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RESERVE

A Summary of Current Program and  
Preliminary Report of Progress

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HORTICULTURAL CROPS RESEARCH

of the

United States Department of Agriculture  
and related work of the  
State Agricultural Experiment Stations.

Section A

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

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UNITED STATES DEPARTMENT OF AGRICULTURE  
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## ADVISORY COMMITTEES

The research program of the Department of Agriculture is reviewed annually by the following advisory committees:

1. Farm Resources and Facilities Research
2. Utilization Research and Development
3. Human Nutrition and Consumer Use Research
4. Marketing Research
5. Agricultural Economics Research
6. Forestry Research
7. Animal and Animal Products Research
8. Cotton Research
9. Grain and Forage Crops Research
10. Horticultural Crops Research
11. Oilseed, Peanut and Sugar Crops Research
12. Plant Science and Entomology Research
13. Tobacco Research

## ORGANIZATIONAL UNIT PROGRESS REPORTS

The source materials used by the advisory committees are of two types. First there are Organizational Unit Reports that cover the work of the Divisions or Services listed below. The number prefixes refer to advisory committees listed above that review all of the work of the respective Divisions or Services.

### Agricultural Research Service (ARS)

### Economic Research Service (ERS)

- |                                   |   |
|-----------------------------------|---|
| 1 - Agricultural Engineering      | 1, 5 - Economic Development                       |
| 1 - Soil and Water Conservation   | 4, 5 - Marketing Economics                        |
| 2 - Utilization -- Eastern        | 5 - Farm Production Economics                     |
| 2 - Utilization -- Northern       | 5 - Economic and Statistical Analysis             |
| 2 - Utilization -- Southern       | 5 - Foreign Development and Trade                 |
| 2 - Utilization -- Western        | 5 - Foreign Regional Analysis                     |
| 3 - Human Nutrition               | 5 - Natural Resource Economics                    |
| 3 - Clothing and Housing          |   |
| 3 - Consumer and Food Economics   | 6 - <u>Forest Service - Research (FS)</u>         |
| 4 - Market Quality                |   |
| 4 - Transportation and Facilities | 4, 5 - <u>Farmer Cooperative Service (FCS)</u>    |
| 7 - Animal Husbandry              |   |
| 7 - Animal Disease and Parasite   | 4, 5 - <u>Statistical Reporting Service (SRS)</u> |
| 12 - Crops                        |   |
| 12 - Entomology                   |   |

## SUBJECT MATTER PROGRESS REPORTS

The second type of report brings together the USDA program and progress for the following commodities and subjects:

- 6 - Forestry (other than Forest Service)
- 7 - Beef Cattle, Part I-a
- 7 - Dairy, Part I-b
- 7 - Poultry, Part I-c
- 7 - Sheep and Wool, Part I-d
- 7 - Swine, Part I-e
- 7 - Animal-Poultry and Products, Part II
- 8 - Cotton and Cottonseed
- 9 - Grain and Forage Crops
- 10 - Horticultural Crops
- 11 - Oilseed and Peanut
- 11 - Sugar
- 13 - Tobacco

A copy of any of the reports may be requested from W. C. Dachtler, Executive Secretary, Grain and Forage Crops Research Advisory Committee, Research Program Development and Evaluation Staff, U. S. Department of Agriculture, Washington, D. C. 20250

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## INTRODUCTION

This report deals with research related to production, processing, distribution, and use of citrus, deciduous, subtropical, and small fruits; vegetables; edible tree nuts; flowers and nursery plants; woody ornamentals; and trees for shade and farm windbreaks. It does not include extensive cross-commodity work, much of it basic in character, which contributes to the solution of problems of other agricultural commodities, as well as horticultural crops. The progress on cross-commodity work is found in the organizational unit reports of the several research divisions of the Department.

This report is organized by problem areas which are shown as the major subjects under the three main divisions in the table of contents. For each of the problem areas there is a statement of (1) the Problem, (2) USDA AND COOPERATIVE PROGRAM, (3) PROGRAM OF STATE EXPERIMENT STATIONS, (4) PROGRESS--USDA AND COOPERATIVE PROGRAMS, (5) PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS.

Research on horticultural crops is supported by (1) Federal funds appropriated to the research agencies of the USDA, (2) Federal and State funds appropriated to the research agencies of the USDA, and (3) private funds for research carried on in private laboratories or for support of State Station or USDA work.

### Research by USDA

Farm Research comprises investigations on introduction, breeding and genetics, variety evaluation, culture, diseases, nematodes, weed control, insects, and crop harvesting, and handling operations and equipment. This research is conducted by the Crops, Entomology and Agricultural Engineering Research Divisions of the Agricultural Research Service.

Nutrition, Consumer and Industrial Use Research. Nutrition and consumer use research pertains to composition and nutritive value; physiological availability of nutrients and their effects; and new and improved methods of preparation, preservation and care in homes, eating establishments and institutions. This work is done by the Divisions of Human Nutrition Research and Consumer and Food Economics Research of the Agricultural Research Service. Utilization research deals with methods of preservation of these commodities through canning, drying, freezing, or combinations of these methods and also with the origination of new forms or combinations of food products. It is also concerned with improved equipment and processes. The work is done by the Eastern, Southern, and Western Utilization Research and Development Divisions; and under contract with State and foreign country laboratories and in cooperation with industry and other organizations mentioned under program for each research area.

Marketing equipment and facility manufacturers also make sizable contributions to research on the development of equipment for handling horticultural crops on the farm, in orchards, or in greenhouses; into and out of packing houses, transportation vehicles, and wholesale distribution centers; and in the retail establishment. They also conduct research on the containers in which the products are moved and on the transportation vehicles from which it moves from one point in the distribution channel to another. Market research institutes and others in marketing economics research are largely concerned with research in consumer preference, market potentials, market promotion and development, and interregional and intermarket competition.

Chemical, fertilizer, and electrical companies make significant research contributions in the development of new materials, or combinations of materials, to produce more efficiently high quality horticultural commodities, through better plant nutrition; improved disease, insect, nematode, and weed control; and the regulation of growth processes by the use of growth regulator substances and other chemicals, light, and environmental control.

There are a few private breeders of horticultural crops and a number of the larger nurserymen, florists, and seedsmen, who spend considerable time and money in the search for and testing of new varieties in the major production areas, sometimes on their own acreage, but usually in cooperation with some grower. The contribution of growers to our overall research effort on horticultural crops is substantial. Certainly, in the field of production their help is indispensable, for most of the laboratory research results must be finally confirmed by larger-scale experiments. The grower cooperates with the USDA, State Experiment Stations, and suppliers of many materials and equipment, usually without compensation except for the experience and knowledge gained.

#### Examples of Recent Research Accomplishments by USDA and Cooperating Scientists

New Fruit and Nut Varieties Released. Two new strawberry varieties were released; namely, SUNRISE, introduced jointly with the Maryland Agricultural Experiment Station, an early ripening, red stele-resistant variety with bright red fruits that remain attractive longer than other red stele-resistant varieties and recommended for areas where red stele is a problem, and EARLIBELLE, introduced jointly with the North Carolina Agricultural Experiment Station, an early ripening, very attractive, firm-fruited variety having greater productivity in North Carolina than the standard Albritton variety and recommended for commercial culture in North Carolina and southward.

Two new blueberry varieties were released; namely, MORROW, introduced jointly with the North Carolina Experiment Station, a canker-resistant variety with good size, attractive color, and very early fruit maturity, for commercial use in Southeastern United States, mainly as a replacement for the Angola variety; and DARROW, introduced jointly with the New Jersey Agricultural Experiment Station, with larger fruits and more reliable yields than the standard Coville variety, recommended as a replacement for the popular Coville variety.

NOVA tangelo (tangerine x grapefruit hybrid), a variety for Florida was released by the USDA because it ripens earlier, has a more attractive orange-colored peel, and has a sweeter and more pleasant flavor than the popular Orlando tangelo.

MOHAWK, a new pecan variety developed by the USDA for culture throughout the southern pecan-growing region was released because of the large size, attractiveness, and high quality of nuts and its early maturity compared to other large fruited pecan varieties.

Beet Leafhopper. Increasing evidence was obtained that it is practical to control this lone vector of the destructive curly top disease in the whole of southeast Idaho by use of crested wheatgrass and controlled range management. During the spring of 1965 the movement of the leafhopper from desert breeding areas to cultivated areas was one of the lowest on record. Only 10 to 20 leafhoppers were found per 100 feet of sugarbeet row. This low population of the leafhopper is attributed to the planting of much of the acreage of its key host plant, Russian-thistle, to crested wheatgrass followed by controlled grazing. This project, initiated in 1959 in cooperation with the Bureau of Land Management, Department of the Interior, to replace 300,000 acres of Russian-thistle with permanent range grass, is showing rapid progress. An excellent stand of crested wheatgrass is well established on more than 100,000 acres of the more important breeding areas of the insect.

Aluminum Mulch for Aphid Control. In experiments at Deerfield Beach, Fla., conducted by Beltsville, Md., and Farmingdale, N.Y., laboratories in cooperation with Florida Agricultural Experiment Station, soil mulch of reflective aluminum foil and black plastic on plots of straight-neck bush squash, planted January 15, aphid-transmitted watermelon mosaic virus infection appeared earlier in unmulched check plots. Aphids flying into the plots were reduced 90% by the aluminum mulch and 29% by the black plastic. At the end of March, 4 weeks after beginning of harvest, 68.5% of check plants were virus infected compared to 51 and 4.1% in black plastic and aluminum mulches, respectively. Although virus infection increased rapidly in April, late infected aluminum-mulched plots produced marketable fruits. In continuing experiments at Beltsville in the spring of 1965 on summer squash, reductions of 75 and 37.5%, respectively, of aphid-transmitted virus infections resulted in plots mulched with aluminum and black plastic, when compared with unmulched check plots.

Insect Vectors of Virus Diseases. At Riverside, Calif., application of diazinon in an experimental peach orchard at petal fall for control of the peach mosaic vector mite was continued for the fifth successive year. The spray program has virtually stopped spread of infection despite the presence of untreated diseased trees.

Temperature Relations in Bean Germination. Low germination in beans is a critical problem for growers and seedsmen. Recent research on this problem has revealed that bean seed, especially limas, are extremely sensitive within the first few minutes to temperature of imbibed water. Imbibition of 60°F or lower within the first few minutes permanently reduced all subsequent growth of the plant. Imbibition at 76°F for the same period, however, protected against subsequent chilling damage. This physiological response to temperature of imbibed water is apparently genetically controlled indicating the possibility that germination and growth of bean varieties may be improved through breeding or by pretreatment of the seeds.

Mechanical Harvesting of Small Fruit. In cooperation with several State Experiment Stations, good progress has been made in mechanizing the harvesting and farm handling of several fruit crops, including cherries, blueberries, prunes, and dates. This particularly true for tart cherries where labor requirements have been reduced by 75 percent and costs by 50 percent.

New Process for Manufacturing Quick-Cooking Dry Beans. Production of dry beans has increased recently, tending to increase an already abundant supply. A new process for making a convenient quick-cooking product promises relief from this surplus. Although dry beans are a rich source of low-cost protein, the modern housewife is often unwilling to spend the time and effort required to prepare beans in the conventional manner. (One of the major reasons is the long soaking time which is necessary.) The California Lima Bean Advisory Board was most anxious to see a quick-cooking bean developed, and has been providing partial financial support for the research on Lima beans. A practical process to produce quick-cooking, essentially non-flatulent, dry Lima beans has now been developed. The processed beans may be prepared for table use in about 30 minutes by simply cooking them in boiling water; no soaking is necessary. In contrast, untreated beans normally require about 15 hours soaking, followed by 1 to 2 hours cooking. The quick-cooking beans have a normal appearance and improved flavor. Several food manufacturers are interested in using the process on several varieties of dry beans.

Bitter Limonin Discovered in Grapefruit Juice. Excessive bitterness is one of the main factors that limits the consumer acceptability of grapefruit juice. In the past, grapefruit bitterness was ascribed to a substance called naringin, whereas the bitterness of navel orange juice is due to another compound, limonin. Department scientists have now discovered that limonin also occurs in grapefruit juice in amounts sufficient (up to 10 parts per million) to contribute significantly to the bitterness of the juice. Limonin has been found both in commercial grapefruit juice products and in juice prepared in the laboratory from fresh fruit grown in Arizona, California, Florida, and Texas. Limonin is located primarily in the pulp of the fruit and enters the juice during extraction. The knowledge that limonin, as well as naringin, contributes significantly to the bitterness of grapefruit provides us for the first time with a sound basis for developing a complete debittering process.

Process for Preservation of Soft and Easy-to-Handle Raisin Paste. Department scientists have made it possible to use surplus raisins for making raisin paste which promises to be a large new outlet. Raisin paste normally sets

into a hard, crystalline mass after only a few weeks' storage. Now a new process has been developed which prevents this hardening by using a heat treatment that requires only a few seconds. Raisin paste prepared in this way remains soft and pliable for months. The treated paste can be economically produced and distributed to the institutional food and bakery trade, where it can be incorporated into such items as filled cookies, coffee cakes, pies, tarts, etc. Delicious products were obtained by a commercial bakery in an experimental lot of various items containing treated raisin paste. The new process is being evaluated by the California raisin industry. The research has had partial financial support from the Dried Fruit Association of California.

New Peach Varieties Show Promise for Processing. Several new freestone and clingstone peach varieties with excellent processing characteristics have been discovered as a result of contract research by the New Jersey Agricultural Experiment Station. The results of this research have shown that harvest about three days prior to full maturity yields better canned and frozen products than comparable produce harvested seven days prior to tree ripeness. In each case the fruit was ripened after harvest prior to processing. One variety, which was highest in vitamin A and C contents and outstanding in flavor, will play an important role in future breeding programs. Processors have expressed an interest in propagating some of the most promising varieties selected from these tests. The availability of these superior peach varieties to the canning and freezing industries should lead to increased consumption of processed peaches.

Commercial-scale Gun Designed for Explosive Puffing of Fruits and Vegetables.

Wider commercial development of the process for explosion puffing of fruits and vegetables, should be greatly accelerated by the newly developed puffing gun designed by EU engineers. Detailed construction drawings of the gun have been made available to industry and it is now commercially available. The newly designed puffing gun has an output nearly four-fold that of earlier models. While explosion puffing has been developed commercially on a limited scale, the availability of a commercial-size gun should promote wide-scale adoption of the process, with resulting increased outlets for fruits and vegetables in the processed food industry.

New Peach Containers Reduce Marketing Costs. New combination fiberboard and veneer wirebound 3/4-bushel boxes cost 12 cents less, including cost of labor to pack them, than the 3/4-bushel veneer baskets. Bruising was reduced from 12 percent in baskets to less than 6 percent in the new boxes. Peach shippers in the eastern states are shifting from veneer baskets to the new jumble-packed boxes. It is estimated that the use of the new containers will save \$3.5 million in 1965 because 75 percent of eastern-grown peaches are being shipped in them.

New Handling and Packing System for Celery. A new system of handling and packing celery, which is in the final stages of testing, involved the development of three-channel weight classifier or sizer. It is capable of weighing 200-225 celery stalks per minute. Estimated labor savings of 7.8 cents per crate, or approximately 35 percent of total labor costs, can be realized with the new handling and packing system.

Reduction of Soft Rot in Bell Peppers. Research conducted in Texas has developed important information on the origin and control of soft rot which causes substantial losses from decay during each marketing season. In the course of studies to develop decay control treatments, research revealed that commercially-waxed peppers developed several times as much soft rot during subsequent holding as unwaxed peppers. Further investigation proved that contaminated brushes in the waxer were spreading soft rot inoculum to originally non-infected peppers. The research demonstrated that frequent disinfection of the brushes with chlorine solution would greatly reduce decay. Other factors contributing to postharvest decay were broken stems, contaminated hydrocoolers, and high water content of the pod tissues. These findings are now being applied in the South Texas pepper industry. In the 15 states with important commercial production of green peppers the on-farm value is about 30 million dollars.

Sweetpotato Quality. Research conducted in North Carolina in cooperation with the State Experiment Station and the Transportation and Facilities Research Division of ARS, has substantially improved handling practices and storage facilities, and reduced decay of sweetpotatoes in the markets. This has been accomplished through introduction of palletized-crate handling for harvest, curing, and storage; adaptation of thermostatically-controlled ventilation and air circulation systems for cooling in storage and floor trench heating systems for prevention of chilling injury, and development of post-storage fungicidal treatments for reduction of decay during transit and terminal marketing. The average annual on-farm value of commercial sweetpotatoes in 19 states is about 70 million dollars.

The results of a study acceptance by a panel of consumers of instant sweetpotato flakes, which were developed by the Southern Utilization Research and Development Division, ARS, indicated considerable commercial potential for the new product. This conclusion is similar to that drawn from the results of an earlier study to measure consumers' reactions to instant white potato flakes. The acceptance of the white flakes has been a major contributing factor to halting the downward trend of per capita potato consumption. In the relatively short period of time since the publication of the final results of the sweetpotato flakes survey, at least four processors have begun producing the sweetpotato flakes at an estimated annual production of three million pounds. Furthermore, the capacity of the current processors is approximately four to five million pounds. Since it takes eight pounds of raw sweetpotatoes to yield one pound of instant, the contribution to the utilization of sweetpotatoes is significant.



## I. FARM RESEARCH

### TREE FRUIT CULTURE, BREEDING AND GENETICS, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. Deciduous tree fruit production is limited by the high cost of growing and by a lack of basic information about its culture. The fruit industry continually needs new disease-resistant scion varieties with improved horticultural tree and fruit characters and rootstock varieties that are winter hardy, disease and nematode resistant, and which make young trees precocious and more fruitful. More precise information is needed about disease and its economic control as well as about the basic physiology of fruit setting, fruit thinning, and growth. The cause and control of internal fruit disorders that originate in the orchard, such as bitter pit and York spot, are still serious problems. The cause and control of the near-disastrous short life of peach trees in the Southeast is a particularly critical problem.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving geneticists, plant pathologists, plant physiologists, and horticulturists engaged in both basic studies and the application of known scientific principles to the solution of fruit growers' problems. Apple breeding research at Lafayette, Indiana, and at Madison, Wisconsin, and cultural and disease research at Wenatchee, Washington, is cooperative with the respective State Experiment Stations as is pear research at Hood River, Oregon, and Riverside, California. Peach breeding and varietal evaluation research at Fresno, California, is in cooperation with Fresno State College and at Prosser with the Washington Agricultural Experiment Station; disease research at Clemson is cooperative with the South Carolina Agricultural Experiment Station; and at Riverside, in cooperation with the California Citrus Experiment Station. Plum breeding and evaluation research at Fresno is cooperative with Fresno State College and at Prosser with the Washington Agricultural Experiment Station. Cherry breeding and evaluation research at Prosser is cooperative with the Washington Agricultural Experiment Station; and disease research at Logan is cooperative with the Utah Agricultural Experiment Station. Apricot breeding research at Fresno is cooperative with Fresno State College.

Federal Stations having deciduous fruit-tree research are Wenatchee, Washington; Fort Valley, Georgia; Mandan, North Dakota; and Beltsville, Maryland. Research at Wenatchee includes variety evaluation of pears; disease research with pear, peach, plum, and cherry; and cultural research with apple and pear. Breeding, variety evaluation, and cultural research is done with peach at Fort Valley and with apple at Mandan. Research at

Beltsville includes breeding and genetic studies of apple, pear, and peach; diseases of apple, pear, and peach; varietal evaluation of peach; and cultural studies of apple and peach.

The Federal scientific effort devoted to research in this area totals 27.1 professional man-years. Of this number 4.0 are devoted to breeding and genetics; 13.5 to diseases; 1.1 to variety evaluation; and 8.5 to culture.

Six 5-year and one 3-year PL 480 contracts are currently in effect:

(1) With the Instituto Biologico, Sao Paulo, Brazil, for studies on basic research on the biochemistry of crown-gall formation (S3-CR-9); (2) with the Israel Ministry of Agriculture for studies on the physiology of rest (dormancy) and its application to fruit growing (A10-CR-8); (3) with the Department of Plant Pathology, University of Milan, Italy, for studies on the etiology and methods of controlling pear Moria disorder (pear decline) in Italy (E15-CR-7); (4) with the Department of Fruit Breeding, Research Institute of Pomology, Skierniewice, Poland, for studies on evaluation of East-European and Asiatic fruit species and varieties recently introduced into Poland which are of value to the U. S. (E21-CR-6); (5) with the Plant Physiology Laboratory, Research Institute of Pomology, Skierniewice, Poland, for studies on growth promoting substances and inhibitors in apple trees during different stages of its development (E21-CR-7); (6) with the Laboratory of Plant Pathology, Institute of Pomology, Skierniewice, Poland, for studies on the epidemiology and control of apple scab (E21-CR-8); and (7) with the Department of Biochemistry, Instituto "Jaime Ferran" de Microbiologia Madrid, Spain, for studies on the chemical and physiological changes in fungi during autolysis (E25-CR-18).

#### PROGRAM OF STATE EXPERIMENT STATIONS

Cultural research at the State Experiment Stations is concerned with problems of stock and scion relationships in tree fruits, the response of tree fruits to application of macro and minor nutrient fertilizers, the inter-relationship of nutrition with local soil types and climatic variations, the water requirements of tree fruits and the interrelationships of fertilization and irrigation, orchard and soil management studies, training and pruning of fruit trees to enhance efficiency of production and to facilitate mechanization of operations, studies on flowering and fruiting with emphasis on chemical thinning, and the effect of all such cultural studies on the nutritive value and consumer quality of the fruit.

Through breeding and varietal investigations, the State Stations are endeavoring to develop disease-resistant fruit of high nutritive value and consumer appeal, adapted to local conditions of growing environment, and better suited to efficient production through adaptation to mechanization. Efforts are being made to develop more effective stock plants for root-stocks.

Cultural and breeding research is supported by fundamental research in plant nutrition, in the biochemistry of the fruiting and flowering response; in anatomical investigations of the stock-scion union; and in histological, cytological, and genetic investigations of problems in breeding.

Research on disease problems in tree fruits is in progress at many of the laboratories of the State colleges and universities. Some scientists are giving special attention to the vast array of viroses of pome and stone fruit crops. Planning, coordination, and pursuit of the objectives of this research are aided by three regional research projects and one interregional research project. Identification, detection, transmission, and fundamental studies of these viruses and the diseases they incite are in progress. Through this research, it has been possible in recent years to recognize that some of the most complex problems in the principal tree fruits, such as apple, peach, pear, plum, and cherry, are the result of specific virus diseases. Since many had gone unrecognized, they became widely spread through plantings and in nursery stocks.

Recent discoveries in this research of pollen and nematode transmission of virus, the control of selected virus with growth regulators, and the detection of viruses in basic dwarfing stocks are evidence of the vigorous research in progress.

Fundamental studies on foliar diseases of tree fruits are providing new knowledge on many bacterial and fungus diseases. Some of these diseases, such as fire blight in apple and pear, bacterial spot and canker in peach, scab in apple, and leaf and blossom blight in cherry are destructive; and even limited control is costly.

Root diseases of tree fruits are being intensively studied at several locations. In some cases, these are diseases that attack established plantings and kill trees. In others, they make an impact on production without death of the trees or create serious replant or establishment problems. Bacteria, fungi, nematodes, and even viruses are involved among these diseases. Replant problems in peach and apple, the winter-kill complex in peach, and nematode in peach are a few of the problems being studied. Mechanisms of pathogenesis and microbial interactions are being investigated in an effort to provide more fundamental knowledge to be used in the control of these diseases.

Fruit rots and internal breakdowns are being investigated. The use of sprays, dips, radiant energy, and other techniques is being tested. In addition, a number of institutions maintain the necessary testing procedures required to provide the elaborate and effective spray production schedules essential to tree fruit production. The total research effort on tree fruits at the State Stations is approximately 86.8 professional man-years, of which 37.7 is for culture, 15.3 for breeding and variety evaluation, and 36.8 for disease investigations.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding

1. Apple. At Lafayette, Indiana, approximately 2300 apple scab (Venturia inaequalis)-resistant seedlings fruited during 1964, and 13 were selected for use as parents. From greenhouse tests, 2575 additional scab-resistant seedlings were planted at Lafayette, Indiana, and 1500 at Urbana, Illinois.
2. Pear. At Beltsville, Maryland, 8870 seedlings are now established in field plantings in an effort to select high quality varieties resistant to fire blight (Erwinia amylovora). Germ plasm sources in 131 accessions of Pyrus species have been established.
3. Peach and nectarine. At Beltsville, Maryland, 22 selections were propagated and 135 saved for further observation. Objective fruit bud hardiness tests of most promising seedlings were made during the dormant period at controlled temperatures. At Fresno, California, 82 peach and nectarine selections were considered worthy of further test. Of these, 1 peach is in the process of introduction, 2 peaches and a nectarine are in advanced stages of testing, 8 out of 13 selections now in grower tests are considered to have commercial promise, and 3 additional ones were placed in grower trials this year. At Fort Valley, Georgia, three selections are being considered for release if their performance in 1965 continues to be promising. At Byron, Georgia, initial seedling and variety plantings were made, starting an anticipated 7-year transition of all plantings from Fort Valley to this new location. At Prosser, Washington, 3 promising peach and 1 nectarine selections were distributed to grower-cooperators for testing.
4. Plum. At Fresno, California, 23 plum selections were saved for further trial and 4 were propagated for second-testing. Five selections now in grower trial appear to have commercial possibilities. At Beltsville, Maryland, the variety collection is being expanded with appropriate parental material to start a hybridization program for the East. At Byron, Georgia, parental material is being assembled to originate varieties for the Southeast.
5. Cherry. At Prosser, Washington, 14 selections from a 1958 planting were propagated for second-testing. At Cheyenne, Wyoming, a very hardy dwarf and fruitful hybrid of P. fruticosa X English Morello was selected.
6. Apricot. At Fresno, California, 27 selections were saved for further observation. Two selections now in grower plantings are considered to have commercial possibilities. At Prosser, Washington, 4 advanced selections were propagated for grower plantings and at Byron, Georgia, over 600 open-pollinated seedlings were planted to initiate a selection program for low-chilling varieties for the Southeast.

## B. Diseases

1. Apple. Fungus diseases. Studies at Lafayette, Indiana, indicate that there are at least 3 genes that independently determine resistance to apple scab (Venturia inaequalis). Promising scab resistant selections have been widely distributed for evaluation.

Preliminary results at Beltsville, Maryland, indicate that the solvent dimethyl sulfoxide may enhance control of apple scab when used in combination with certain fungicides. The trunk injections and foliar applications of dimethyl sulfoxide, however, were somewhat phytotoxic at the concentrations used.

The final report of the P.L. 480 project, in Poland, on epiphytology of apple scab (E21-CR-8) offers additional evidence on the epidemiology which supports the fact that both ascospores and conidia are airborne. Development of the ascospore stage and discharge of ascospores are directly affected by weather factors of both temperature and moisture. Development of conidia is continuous in lesions but their discharge is increased during wet weather. In general, it appears that spore dissemination of the apple scab fungus occurs during conditions most favorable to infection. Work with eradicant and protective fungicides supports previous reports that Dodine is the most effective material. It not only prevents infection when applied as a protectant but also prevents sporulation when applied as post-infection treatment. Faltan and Captan are also effective materials but not as effective as Dodine. The results substantiate and confirm the results obtained in America.

At Hood River, Oregon, Morestan fungicide was the most outstanding new material tested for use against powdery mildew (Podosphaera leucotricha). Retardation of terminal growth was observed during the duration of the test, but normal growth resumed when the fungicide applications ceased. A three-year study on the effect of dosage and application frequency of dodine-karathane sprays was concluded. It is now recommended that growers adjust the dosage level of dodine-karathane sprays in accordance with the interval between sprays. The addition of various surfactants to karathane revealed that of 14 surfactants tested, only 5 improved the effect of karathane.

Virus diseases. Ring russet virus. Losses due to the ring russet virus were slight at Wenatchee, Washington, during 1964. By inoculation, however, typical symptoms were produced on fruits of Early McIntosh. By mid-July, the russet rings resembled symptoms of the star crack virus.

Green crinkle or false sting virus. This virus is causing greater concern to north-central Washington apple growers, and increasing numbers of inquiries were made during 1964. Three forms of this virus have been graft transmitted with the incubation period varying from one to two years.

Bark pox of apple. Bark disorders of Delicious are of great concern to Northwest growers. After many unsuccessful attempts, graft transmission of a bark measles condition has been accomplished. Three and four-year incubation periods were required for symptom expression.

2. Pear. Fungus diseases. Fire blight (Erwinia amylovora). At Beltsville, Maryland, 38 percent of the seedlings that flowered became infected with blossom blight. Of those seedlings infected with blossom blight, 78 percent were later observed to have fire blight progressing into twigs and branches. In seedling populations, the incidence of fire blight infection was correlated with the incidence of flowering.

Fire blight resistance to 6 Pyrus communis varieties was found to be related to the ability of injured leaf tissues to produce bactericidal quantities of hydroquinone. Fire blight-resistant varieties produced more hydroquinone enzymatically than did susceptible varieties. Leaf homogenate hydroquinone levels in resistant varieties were 20 to 40 times greater than that required to stop in vitro growth of the fire blight organism.

The incidence of fire blight in the Hood River, Oregon, area was higher in 1964 than in any other time in recent years. The need for fire blight-resistant varieties or better control measures was very obvious. Research on the use of the solvent dimethyl sulfoxide with antibiotic sprays was initiated.

Powdery mildew (Podosphaera leucotricha). Liquid formulations of karathane were found to be more effective than wettable powder in the control of powdery mildew on pear seedlings at Hood River, Oregon.

Virus diseases. Pear blister virus presently does not have a very high incidence in Northwest orchards, but it is causing considerable loss in one Red Bartlett orchard and must be considered as a potentially serious virus. In 1964, 20 pear species and 67 varieties at Wenatchee, Washington, were test inoculated with this virus.

Stony pit virus is still a potentially serious threat to pear-growing areas. Since grower interest is being manifested in some of the newly introduced pear varieties, a project was initiated in 1964 at Wenatchee, Washington, to test three strains of stony pit virus on 11 new pear varieties.

Pear decline. Experimental trees on oriental pear rootstock (Pyrus ussuriensis and P. serotina) continue to show quick decline at Wenatchee, Washington. At Riverside, California, Bartlett pear trees inoculated with pear decline virus produced more terminal growth the first year than did healthy trees. The increase in terminal growth was more pronounced on oriental rootstocks than on Pyrus communis rootstock. This virus-induced acceleration of growth on oriental rootstocks may explain the physiological stress observed at the graft union.

Research to study pear decline in Italy is sponsored by the United States under the provisions of P L 480 project E15-CR-7 entitled "The etiology and methods of controlling pear moria (decline)." Moria is presumed to be of the same etiology as North American pear decline, but in Italy the disorder seems less specific and occurs on trees of standard varieties growing on P. communis rootstock.

3. Peach. Bacterial diseases. Bacterial leaf spot. At Beltsville, Maryland, greenhouse tests showed oxytetracycline (Terramycin) gave protection against bacterial spot at 42 ppm. Inclusion of dimethyl sulfoxide (DMSO) significantly enhanced control. Less disease was noted on inoculated terminal leaves developing after the spray was applied, suggesting some translocation.

Bacterial canker. At Clemson, South Carolina, Pseudomonas syringae was transmitted by contaminated scion buds in normal nursery practice. Spraying trees with a P. syringae suspension following pruning produced bud and branch cankers from which the bacteria were recovered. Fall and winter applications of copper sulfate and streptomycin failed to control canker in a heavily infested mature orchard. Foliage appeared to increase resistance to the bacteria, but nature of the resistance is unknown.

Fungus diseases. Root and crown rot. At Clemson, South Carolina, root and crown rot reappeared after an absence of 4 years. Hyphae of Pythium ultimum and zoospore germ tubes of Phytophthora cactorum were observed penetrating peach roots by means of infection pegs produced from appressoria. Excised roots did not attract the zoospores. P. ultimum failed to colonize tissue having secondary wall thickening, whereas P. cactorum colonized all tissues. The latter produced significantly more sporangia in darkness than in light prior to sporangial formation.

Virus diseases. Peach mosaic. At Riverside, California, 3 strains of the virus have been defined. Cross-protection in peach by a mild strain is dependent upon the species source of the challenging severe strain. Dimethyl sulfoxide (DMSO) appears to have some viricidal properties and to be a useful solvent for known viricides. At Logan, Utah, peach mosaic infection is at a low level, apparently due to the infected tree removal program. However, some infection by an off-type strain of mosaic has been confirmed by greenhouse inoculation experiment.

Peach X-disease. At Wenatchee, Washington, X-disease is of little economic importance where an effective insect control program is used. Eight clones ranging from mild to lethal have been freed of contaminating viruses by use of stone fruit filter hosts. At Logan, Utah, field surveys showed X-disease increasing in Utah. Most diseased trees were in orchards over 15 years old growing near mountains and interplanted with infected sweet cherry trees. No diseased trees under 6 years old were found.

Mule-ear virus. At Riverside, California, fruit and/or leaf symptoms caused by this virus increased in severity during the second year of infection in 17 of 18 varieties tested; only Gold Dust remained symptomless. Fruit production of infected trees was about half of that on healthy trees. All known cultures produce symptoms of Prunus ringspot virus on appropriate hosts.

4. Sweet Cherry. Virus diseases. X-disease virus. At Logan, rapid spread continued in some Utah sweet cherry orchards. Wilt and decline symptoms indistinguishable from those induced by X-disease virus were observed in many trees. Of 93 sweet cherry trees topworked on Mahaleb framework stocks in 1951, none have died although 17 have branches infected naturally. Seedlings of 2 varieties which appear resistant are being grown as possible sources of resistance for a breeding program. At Wenatchee, Washington, both Chinook and Rainier were severely affected by the little cherry virus. In a 5-year test, reduction of tree and fruit growth of Montmorency on two little cherry strains was noticeable but far less severe than in a comparable planting at Corvallis, Oregon.

Rough fruit of sweet cherry. An increasing number of trees are producing rough lumpy fruit in Western orchards. At Wenatchee, Washington, twisted foliage and twig necrosis, similar to symptoms produced by the twisted leaf virus on Bing trees, have been observed. Symptoms of lumpy fruit were produced on a Bing tree but not on Van, Sam, Lambert or Montmorency trees receiving grafts from an apricot ring pox strain. The virus moves slowly but more rapidly in Van than in Bing or Lambert. No distinctive leaf symptoms have been noted in Utah.

Short stem of sweet cherry. At Wenatchee, Washington, a virus causing symptoms similar to the short stem disease has been transmitted to Bing and Lambert and is being tested on 75 stone and pome fruit trees. The disease is spreading in a Medford, Oregon, Lambert orchard.

Mottle leaf. Some economic loss of sweet cherries continues in canyon foothill orchards of the Pacific Northwest where P. emarginata occurs naturally infected with mottle leaf virus. At Wenatchee, Washington, Bing, Napoleon and Lamida express symptoms readily; John Innes 345 is moderately affected; Schmidt, Sue, Royal Duke, Morello cherries, Utah almond and P. tomentosa and P. davidana seedlings are symptomless carriers; and P. andersonii and P. subcordata are immune.

Necrotic rusty mottle. At Wenatchee, Washington, tests with a moderate, pure strain of necrotic rusty mottle virus showed all 10 plums tested immune; Sodus cherry was moderately affected; other cherry varieties, Shiro-fugen flowering cherry and P. mackii were symptomless carriers; and Elberta peach was partially resistant.

Another mild strain was identified in 1964 from 2 sweet cherry trees in Utah. Necrotic leaf symptoms had developed for several years but mottle

symptoms were absent previously. Transmission to Lambert cherry was achieved in 1964, but leaf necrosis and mottle symptoms were very mild.

Rugose mosaic. Screening and host range studies with a single clone of this virus at Wenatchee, Washington, confirm reports that rugose mosaic is a strain of Prunus ring spot virus.

New disorders. Near Wenatchee, Washington, a previously undescribed abnormality appeared in 1964 on a Bing sweet cherry tree. One large leader bore blossoms with green petals. The developing fruit became somewhat elongated, and the style persisted in an elongated form resembling a hummingbird's beak. Transmission experiments are underway.

A spur-type Bing tree near Yakima, Washington, appeared 'clean' on the basis of Shiro-fugen flowering cherry tests. However, a nursery which topworked a Van tree with buds from the spur-type tree in 1963, discovered that not only did the buds fail to grow but that Van branches near the inserted buds produced spiral or S-curve growth. Close examination of the tree showed similar spiral growth. Exploratory host range studies have been initiated.

5. Sour cherry. Sour cherry yellows complex. In Wisconsin, infected seeds again were produced on healthy trees without infecting the mother trees. Additional data indicate that prune dwarf symptoms can develop with one cool night out of three and that the temperature effect is independent of light. Some properties of a plum-line pattern virus obtained from sour cherry have been determined.

6. Apricot. Rusty mottle virus complex. In Utah, Wilson Delicious trees inoculated in 1948 with various rusty mottle viruses show only reduced rate of growth. Trees inoculated with rusty mottle and mild rusty mottle are smaller than those inoculated with Utah Dixie rusty mottle virus. All trees inoculated with necrotic rusty mottle died, half of the rusty mottle and one-fourth of the mild rusty mottle trees died.

Ring pox. A Moorpark tree with typical symptoms was found in Washington County, Utah, in 1964. Transmission studies are underway. Previously this was found only in symptomless peach and sweet cherry. Natural spread of ring pox virus, which occurred in 1963, was confirmed by transmission in 1964. In Washington, the two forms recognized have the same host range but cause somewhat different symptoms. Royal (Blenheim) is a symptomless carrier of both forms, but 2 out of 13 so-called Royal collections expressed fruit symptoms. Two additional fruit-expressing varieties were found in 1964, while 6 varieties and P. mackii seedlings were shown to be symptomless carriers.

7. Plum. Rusty blotch. Incidence of this disease increased from about 50% in 1960 to over 70% in 1964 in 2 Kern County, California, orchards. No known Santa Rosa plantings in California are entirely free of this most serious disorder of Japanese-type plums. Climatic conditions and cultural

practices do not affect symptom expression or spread; no pattern of spread could be detected. Some trees have been affected for 9 years without showing more than mild symptoms while others deteriorate rapidly. Correlation is poor between leaf symptom and reduced fruit production on affected trees. Possibly 2 disease factors are present in the same trees.

8. P L 480 Research. United States-sponsored research in Brazil on the biochemistry of crown gall formation (S3-CR-9) showed that more indoleo-acetic acid (auxin) is formed by healthy than by diseased tissue and that autoxidation of indole-3-acetic acid plays a major role in plant growth regulation. Research on fruit tree viruses in Poland (E21-CR-27) indicates that many of the fruit tree viruses known in America also occur in Poland. Certain diseases are reported in Poland which do not yet occur in America, and this information should help to set up safeguards to prevent their entry. The more important of these diseases is plum Sarka (plum pox), a fruit splitting and cork forming disorder of apples, and a ring-russet disease of pears.

### C. Varietal Evaluation

1. Apple. At Blairsville, Georgia, 380 apple varieties are established in variety plantings. Most of these varieties will bear fruit for the first time this year and will be evaluated both for possible commercial planting and parents for the apple breeding program. More than 190 apple varieties at Mandan, North Dakota, are being evaluated for the Northern Great Plains.

The evaluation of 32 Delicious strains continues at Wenatchee, Washington. Storage tests during the last 2 years indicate that spur types are later maturing and generally poorer in quality than conventional strains.

2. Pear. A total of 466 pear varieties have now been assembled in field plantings at Beltsville, Maryland, and some of these will begin to fruit in 1965; 78 varieties are under test at Mandan, North Dakota.

3. Peach. At Fresno, California, the Delight peach ripening 10 days before Elberta, had a soft suture and poor color. Mayflower, John River, and Freedom had excessive bud drop; but most varieties received adequate chilling during the 1964-65 winter, the third warmest in 15 years. At Beltsville, Maryland, a third successive drought year hampered comparison of midseason and later varieties. Marcus was eliminated from further consideration because of its extreme split-pit tendencies. Earlired showed less tendency than Collins to bacterial spot. Early Redhaven from Washington State was again promising. At Byron, Georgia, a new varietal orchard was started.

4. Cherry. At Prosser and Wenatchee, Washington, sweet cherry fruit buds that survived the December freeze, ranged from 5 to 50 percent, depending upon variety. Spring frosts have further reduced the fruit buds. Van

continues to show its superiority for early bearing over Bing and Lambert.

5. Apricot. At Prosser, Washington, growers are extensively testing 3 Department and 1 Canadian selections as replacements for the Wenatchee variety.

6. P L 480 Research. Under United States sponsorship, in Poland, the evaluation of East European and Asiatic species and varieties of fruit plants (E21-CR-6) indicates that hardy peaches which withstood winter temperatures of minus 33 degrees F. hybridize with commercial high quality varieties. Some, however, are pollen-sterile similar to J. H. Hale and can be used only as female parents. Efforts should be made to import these varieties to America to serve as winter-hardy germplasm. Hardy sweet cherry varieties appear even more promising - they withstand low winter temperatures, are hardy in bud, and produce good quality fruit. Two varieties of apples, Rosovoye Prevoskhodnoje and Suislepper, mature very early and produce good quality fruit.

#### D. Culture and physiology

1. Apple. Rootstocks. At Wenatchee, Washington, biochemical research to determine the physiology of size-differentiating rootstocks, East Malling (EM) IX and XVI, showed that EM IX has higher protein and nitrogen than does EM XVI. No difference was found in phloridzin or organic acids, but EM XVI has a slightly higher level of total phenols than does EM IX. B-Nine, the growth-retarding chemical, reduced growth more in EM XVI than in EM IX while gibberellin increased growth more in EM IX than in EM XVI. Respiration was greater in EM XVI than EM IX.

Growth retardants. At Wenatchee, Washington, foliar applications of 1000 ppm of growth retardant N-dimethyl amino succinamic acid (B-Nine) reduced vegetative growth up to 35 percent. Applications of 2000 ppm and higher reduced fruit size by about 10 percent. B-Nine applications in 1963 had a dramatic effect on increasing bloom in 1964. Because of this increased bloom, yields of Golden Delicious trees were increased. Delicious apples sprayed with B-Nine were 2 to 4 pounds firmer when removed from storage in May. B-Nine also greatly reduced the incidence of storage scald on Delicious apples. Research indicates that B-Nine is a possible antagonist of natural gibberellins. Lima beans sprayed with both B-Nine and gibberellin grew to normal size while those plants sprayed only with B-Nine and reduced growth.

Chemical fruit thinners. Research at Wenatchee, Washington, showed that Sevin had to be applied directly to the developing fruit for fruit thinning to occur. The main metabolite of Sevin was found to be an unknown water soluble component containing both the naphthol ring and the side chain carboxyl carbon molecule.

P.L. 480 Research. United States-sponsored studies, in Poland, on growth-promoting substances and inhibitors in apple trees.....(E21-CR-7) showed that a growth inhibitor, phloridzin, promoted flower-bud initiation in apple.

2. Pear. Growth retardant. Foliar sprays of N-dimethyl amino succinamic acid (B-Nine) were found to reduce vegetative growth in pears at Beltsville, Maryland. Fruit set was not affected by B-Nine sprays at Wenatchee, Washington.

Pear psylla toxins. Biochemical studies on the pear psylla toxins at Wenatchee, Washington, showed that both pear psylla adults and nymphs transfer  $C^{14}$  organic components to pear seedlings during feeding. More transfer was from nymph than adult feedings. The  $C^{14}$  was rapidly distributed throughout the plant, but the roots contained more  $C^{14}$  than did the tops of the seedlings.

Winter injury. The December 16 freeze ( $-13^{\circ}F$ ) at Wenatchee, Washington, injured fruit spurs on the Bartlett and Anjou varieties. Both the pith and phloem were killed, but histological examination showed only slight injury in the cambial area. It is not believed that the spur damage will interfere with fruit production.

3. Peach. Rootstocks. At Fresno, California, seeds of Nemaguard and a Nemaguard derivative germinated better and seedlings grew into appreciably larger trees than seedlings of 18 Nemaguard X Okinawa hybrids and 3 acrita nematode-resistant Nemaguard selections.

Chemicals for thinning. At Wenatchee, Washington, trees of Dixired and J. H. Hale were sprayed with 150 and 300 ppm of 3-CPA (3-chlorophenoxy-alpha-propionamide) at 23, 31, and 41 days after full bloom. Only the 41 day spray at 300 ppm reduced fruit set, and this was sufficient to be of commercial significance on J. H. Hale.

Fruit development. Peach fruits have an optimum range of night temperatures for ripening; warm temperatures accelerate ripening during early, but delay it during later fruit development stages; whereas abnormal cold always delayed fruit ripening.

P L 480 Research. The physiology of rest(dormancy) and its application to fruit growing was studied in Israel under United States sponsorship. The relationship of light and starting of growth after chilling is new: flower-bud break is inhibited and leaf-bud break promoted by light. Red light was the most effective kind and the phenomenon appeared to be controlled by phytochrome system since the red-light effects were reversed by far-red light.

4. Cherries. Rootstocks. At Prosser, Washington, mahaleb rootstocks and Montmorency interstocks promote early bearing of sweet cherries. Strains

of mahaleb differ in their ability to promote early bearing.

Growth retardants. At Wenatchee, Washington, B-Nine (N-dimethyl amino succinamic acid) at 500 to 2000 ppm advanced cherry maturity 3 to 5 days on several varieties without reducing fruit size, firmness, or quality. Fruit set was not affected. Treatment a second consecutive season was not as effective in retarding growth.

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SMALL FRUIT CULTURE, BREEDING AND GENETICS,  
DISEASES, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. New improved varieties of small fruits and grapes are needed that have broad regional adaptation suitable for modern commercial use. Needs include large (for ease of picking), firm-fruited (for best handling), disease-resistant varieties for freezing and for long distance or local marketing, with a sequence of ripening throughout the season. Determination of causal agents of new diseases is needed, and methods should be developed for effective and economical control of important fungus, nematode, and virus diseases of berries and grapes, with emphasis on identification and control of viruses in strawberries, raspberries, and grapes. The testing and critical evaluation of varieties for yield and important horticultural characters, such as fruit size, firmness, color, and quality are needed in relation to regional adaptation. Also needed are improved cultural practices in propagation and plantation management that will result in high production of good quality fruit and reduced production costs. This entails new information on environmental factors limiting production and on interrelationships of temperatures, soil moisture, diseases, and nutrition on plant growth, hardiness, and productivity.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving geneticists, plant pathologists, and horticulturists engaged in both basic studies and the application of known scientific principles to the solution of growers' problems. European bunch-grape breeding, disease, varietal evaluation, and cultural research at Fresno, California, is cooperative with the Fresno State College. Strawberry breeding research at Salisbury, Maryland; Willard, North Carolina; and Corvallis, Oregon, is cooperative with the respective State Experiment Stations; and in addition, strawberry breeding and cultural work at Carbondale, Illinois, is cooperative with Southern Illinois University. Raspberry and blackberry breeding research at Corvallis, Oregon, and Carbondale, Illinois, is cooperative with the Oregon Agricultural Experiment Station and Southern Illinois University, respectively. Blackberry cultural research at Corvallis, Oregon, is cooperative with the Oregon State Agricultural Experiment Station. Blueberry breeding research at Gainesville, Florida; Tifton, Georgia; Jonesboro, Maine; and Ivanhoe, North Carolina; and breeding and disease research at Hammonton, New Jersey, is cooperative with the respective State Experiment Stations. Cranberry breeding research at East Wareham, Massachusetts; and disease research at New Brunswick, New Jersey, is cooperative with the respective State Experiment Stations. Breeding research (strawberries and raspberries) is done at the USDA Horticultural Field Station, Cheyenne, Wyoming. Breeding, disease, varietal evaluation, and cultural research with Eastern bunch grape, and breeding research with muscadine grape, is carried on at the USDA Horticultural Field Station, Meridian, Mississippi. At Beltsville, Maryland, breeding, variety

evaluation, and disease research is done with eastern bunch grape, strawberry, blackberry, blueberry; and cultural studies are done with the eastern bunch grape, blueberry, blackberry, and strawberry.

The Federal scientific effort devoted to research in this area totals 14.8 professional man-years. Of this number 7.9 is devoted to breeding; 4.6 to diseases; 1.6 to variety evaluation; and 0.7 to culture.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Cultural research on small fruit at the State Stations is concentrated on strawberries, blueberries, grapes, and cranberries with only limited research on raspberries, blackberries, other brambles, and elderberries. Research is underway to study fertility levels, fertilizer placement, nutrient sources, and mulches in relation to strawberry production. Research with blueberries includes investigation of the effect of pH on plant growth, mineral nutrition, methods of propagation, and pruning. Grape investigations include mineral nutrition, spacing, effect of plant regulating chemicals on growth and fruiting, rootstocks and efforts to mechanize pruning and harvesting. Soil and nutrient requirements of cranberries are being investigated.

Breeding and varietal research is underway with strawberries, blueberries, grapes, cranberries, blackberries, raspberries, dewberries, and elderberries. Such research is designed to increase efficiency of production through better locally adapted varieties combining disease resistance with good horticultural type, high nutritive quality, and consumer appeal. Consumer acceptance is evaluated through chemical evaluations of nutritive quality and taste panel reaction. The fruit is processed and consumer acceptance of the processed product is evaluated. The breeding and varietal studies are supported by fundamental investigations of genetics and cytogenetics.

Scientists at the State Stations are providing effective research programs on diseases of small fruits in all of the principal producing areas. The wide range of climatic and soil conditions under which these crops are grown, in addition to the rapid changes in variety and in harvesting requirements, complicates the development of effective disease control. Station scientists are conducting research on the destructive viruses of strawberry which is leading to the development of more effective systems for the elimination of these diseases. Leadership in research on the nematode transmission of virus diseases of small fruits continues at several Stations. Research on fruit rots in grapes and new knowledge on enzymatic relationships in these diseases are providing substantial contributions. A number of diseases of strawberry, bramble, and grape require specialized chemical controls, which are being made more effective and less costly through research. Effective treatments for the control of berry rots at harvest and transit are also being developed through research at the State Stations.

The total research effort on small fruits at the State stations is approximately 38.4 professional man-years, of which 12.6 is for culture, 20.0 for breeding and variety evaluation, and 5.8 for disease investigations.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding

###### 1. Grape

a. American bunch grape. The principal objective at Beltsville, Maryland, is breeding for black rot disease resistance; and at Meridian, Mississippi, emphasis now is on origination of muscadine-bunch grape hybrids. At Beltsville, young grape leaves were found to be 5 to 6 times more susceptible to black rot infection by artificial inoculation than fully expanded leaves. Seven selections that are tolerant of black rot and Pierce's Disease virus are being tested at several Experiment Stations. Thirty 3rd and 4th generation muscadine-bunch grape hybrids that are highly fertile are now under test and are being evaluated for resistance to diseases, particularly Pierce's Disease virus.

###### b. Muscadine grape.

Muscadine grape breeding. Muscadine grape breeding is aimed primarily at origination of perfect-flowered varieties adapted to southern growing conditions. Four selections from the work at Meridian appear promising as potential varieties and now are being tested extensively. Forty-one other muscadine selections are being tested. Tetraploid muscadine seedlings have been weaker and more susceptible to diseases than diploid seedlings.

c. European bunch grape (Vinifera). Eighty-four seeded and 34 seedless selections are being evaluated for table-type purposes at Fresno, California. Two advanced selections F-35-33, an early white seedless selection, and F27-31, a midseason seeded black grape, are in the final stages of evaluation before possible introduction. Four rootstock selections appear promising for commercial purposes because of their resistance to nematode and Phylloxera which are the main objectives in the work. Extensive tests of selection 16-154 indicate that it may be worth introducing as a rootstock for Thompson grown for raisin production and wine purposes and may be desirable as a rootstock for other varieties also.

2. Strawberry. At Willard, North Carolina, the Earlibelle variety was introduced after extensive testing under the number of NC US 2486. This is an early ripening, large, firm-fruited variety that yields about 25 percent more fruit than Albritton. The plants are highly resistant to leaf spot and leaf scorch. One more selection is being propagated for possible

introduction from the work in North Carolina. Several of the newer selections yielded heavily in a season when most selections and varieties yielded lightly, and these appear promising as potential varieties. They are being propagated for extensive testing.

In Maryland, the Sunrise (Md-US 2601), was named and introduced. It is an early ripening variety with multiple resistance to red stele and with foliage that is very resistant to leaf scorch and mildew. It appears particularly well adapted to the southcentral part of the United States. Four new selections (Md-US 2787, 2921, 3068 and 3082) also appear promising out of more than 275 on test. The Md-US 3365 has transmitted very good resistance to red stele to its seedlings. US 4384 produced the largest (primary berries 2-1/4 inches in diameter) and most fruit of any selection that has fruited at Beltsville, and it appears promising as a parent for its fruit size.

At Carbondale, Illinois, 65 advanced selections from the breeding work at that Station are on second test.

At Corvallis, Oregon, selections made in 1964 for high quality, commercial-type fruit were generally susceptible to red stele and to virus. Four of the older selections that are resistant to red stele and virus tolerant appear promising. Hybrids of F. chiloensis selections from Gold Beach, Oregon, with commercial varieties were the most red stele resistant. Most seedlings failed to survive the red stele screening tests even though the parents were resistant to red stele. Two selections (Ore. US 2575 and Ore. US 2931) appear promising as commercial types.

At Cheyenne, Wyoming, 8 advanced selections were placed under test at several locations, including Experiment Stations in the Great Plains region. Three of the advanced selections yielded as well as or better than Radiance and were considerably firmer than Radiance.

3. Raspberry. At Carbondale, plants derived from one or more Asiatic species had very little winter injury, and this winter hardiness appears to be associated with the high resistance to defoliation by Septoria leaf spot and with the ability to withstand fluctuating winter temperatures. One clone of such parentage was propagated for testing throughout the upper south area of the United States. This clone has also remained mosaic free in the field for 12 years. Several analogous tetraploid clones had large fruit size and these will go into advanced tests this year. Two black raspberry selections (NC 307 and NY 628) appear promising and are being propagated for testing in the upper south. Among the raspberry selections that were made in 1962 at Cheyenne, Wyoming, some yielded 6 to 7 times more fruit than others; all selections are summer fruiting types that bear on the current season's canes.

4. Blackberry. At Beltsville the US 1493 and US 1503 thornless selections are being propagated for introduction. Other promising selections include

US 1482, US 1523 and US 1526. At Carbondale, Illinois, promising winter-hardy, good quality selections have been obtained in seedlings of thornless hexaploid blackberries, tetra- and hexaploid blackberry-raspberry hybrids, and tetraploid species raspberry by cultivated types. Cytological examination of hexaploid plants revealed the first evidence of structural rather than cryptic differentiation of the chromosomes of different species in Rubus. Two new thornless selections have exhibited a high degree of winter hardiness the past two years. These have been used as parents in further breeding for thornlessness. At Corvallis, 3 thornless selections appear very promising as commercial types for frozen pack and canned fruit. Five new thorny blackberry selections were selected for their early harvest period and high quality fruit. Seedlings with Merton Thornless parentage were found to possess large seed about equal in size with Oregon Evergreen, which is objectionable. About 25 percent of the new seedling progenies that had Austin Thornless type parentage were thornless.

5. Blueberry. New work was initiated on interspecific hybridization of blueberries in cooperation with the New Jersey Station. In New Jersey, seven selections (G-3, G-99, G-107, G-111, G-115, G-119, and G-122) fruited heavily following a severe test winter; and they all appear to be potential new varieties. They have been propagated and sent out for an extensive testing. The G-71 was named Darrow and introduced. Plants of Darrow are erect, vigorous, and consistently productive. The fruit is borne in medium-sized, attractive clusters. The berries are as large as Coville, firm, light blue in color, with a medium-sized scar similar to that of Coville. The berries are aromatic and highly flavored with a tart to mildly tart taste, depending on maturity. The fruit neither drops nor cracks in periods of wet weather. Darrow is being introduced because its fruits average larger, and it is a more consistent bearer than Coville and ripens about with it. It is, therefore, considered as a replacement for Coville.

In North Carolina, the NC 678 selection was introduced under the name of Morrow. It is a very early ripening, large fruited, canker-tolerant variety for the southern part of the United States. NC US 690, a large fruited, late ripening, very vigorous and productive selection was propagated and is being placed on test with growers in North Carolina.

In Maine, Me US 1-5 is being propagated for test with growers in a number of places. It is a highbush that has been consistently winter hardy and productive.

In Michigan, a favorable season indicated the following selections to be promising: E-36, 55, 96, 132, 158, 170, 176, 184 and 204. All of these appear more resistant to low winter temperatures than selections made in New Jersey.

In Georgia, of the six older selections that appear promising the T-65 is about 10 days earlier than Woodard. T-92 is another early selection but seed size is large.

Several very early ripening selections from the breeding work in Florida appear promising as commercial types. Some of these have very short chilling requirements combined with productivity and medium-sized fruit of good flavor and are being propagated for wide testing.

## B. Diseases

1. Grape. Virus diseases. Eight viruses are now known to be present in grapes in California. Their detection, refinements of index methods, effects of virus complexes and establishment of virus-free stocks are the main problems in the research work. From work in California, all known grape viruses usually can be inactivated in shoot tips propagated under mist from plants that have been held 60 or more days at a constant temperature of 100°F. Treatments were more successful if started in October than in April. At Davis, 171 grape varieties have survived the heat treatment. During 1964, 6 rootstock and 30 scion varieties were added to the virus-free foundation vineyard at Davis, bringing the total number of varieties in this planting to 98. From an old experimental vineyard, established about 1889 with own rooted vines, all of 34 indexed varieties have been virus-free. Fanleaf virus and Xiphinema index nematodes vector have survived for 5 years on root remnants. Foliar applications of 2-4-D amine on infected vines kills the root system in about 1 season and soil can thereby be decontaminated of fanleaf virus. At Beltsville, Maryland, Baceo 22A indicator vines have failed to show reliable symptoms of leaf roll virus when inoculated with known sources of leaf roll.

2. Strawberry. Virus diseases. At Corvallis, Oregon, virus-free strawberry plants were obtained by excising tips from very young stolons and growing them in culture media or in sterilized sand under mist. Four US-Oregon selections (2873, 2974, 2988, and 2996) and one California selection (56.49-1) were found to be very tolerant to a severe yellows virus complex in an extensive screening program. Indexing of first year's selections grown at Corvallis indicated that mottle and mild yellow edge were the most prevalent virus components and that 65% of the selections were infected. Inoculations of Fragaria chiloensis clones collected along the Oregon coast revealed 12 different clones that were highly tolerant to a severe yellows virus complex but none of the clones were immune.

At Beltsville, plants derived from cultured excised tips have yielded 8 varieties that are free of all known viruses for the first time. Latent A-free stocks were also obtained by heat treatment followed by excision of axillary buds, and these stocks have been made available to State Certification Programs. In a comparison of Latent A-free versus Latent A-infected plants, the Latent A-free plants in general produced more runners and more and larger fruit than Latent A-infected plants. Stocks of 20 strawberry varieties free of known viruses and diseases were available to researchers and certified plant producers.

Fungus diseases-Red stele. Six *Potentilla* species from Europe and Asia and *Potentilla glandulosa* of the western United States were found to be susceptible to one or more races of *Phytophthora fragariae*, and these *Potentilla* species may be the wild host reservoir of *Phytophthora* in western United States. Collections of *P. fragariae* from California, Oregon, and Washington had 5 races similar to those in eastern United States plus 2 new races that were labeled A-7 and A-8. The A-8 is pathogenic to Yaquina, a *Fragaria chiloensis* clone that is being used extensively for red stele resistant germ plasm. Surecrop, which is resistant to at least 4 races of *P. fragariae*, was found infected in 2 fields in eastern United States.

3. Raspberry and blackberry. The heat labile mosaic virus was inactivated in red raspberry by heat treatment at 100°F. for 96 hours. All commercial Latham stocks when surveyed had HLMC and 40% also carried Raspberry yellow net virus. Latent viruses were revealed in raspberries when alpine strawberry, Turkish tobacco, *Chenopodium amaranticolor*, and *C. quinoa* were used as indicators. A mechanically transmissible ring spot virus was found in a red raspberry from a planting in Maryland. Nineteen raspberry varieties were found free from all detectable viruses. Twenty-one varieties of blackberries were found free of detectable viruses when indexed on *R. henryi*. A new species of *Phytophthora* was isolated from infected roots of Canby red raspberry from Washington State, and this has been named *Phytophthora rubi*. The *P. rubi* caused death of varieties like Canby which are susceptible to the wet soil raspberry root rots in the Pacific Northwest. A survey of parasitic nematodes in raspberries in Maryland and 7 other eastern States revealed 31 different nematode species of which *Xiphinema americanum* and *Pratylenchus penetrans* were most common. Some stocks of virus-free raspberries have remained virus-free in isolated commercial nurseries for 3 years.

4. Blueberry. Red ring spot virus has continued to spread. One block of Burlington and Jersey that are interplanted had 51% of the Burlington infected this past season, but Jersey had no plants with symptoms. Red ring spot has invaded the seedling plantings and vectors are yet unknown. Shoe string virus is also spreading but not so rapidly as red ring spot. Good control of anthracnose was obtained by the use of dithane M-22 plus the X-77 spreader sticker. Dyrene also reduced infection of anthracnose.

5. Cranberry. Helicopter applications of fungicides for fruit rot control of cranberry indicated that manzate D was the most effective fungicide when applied about 25 to 35 gallons per acre. All fungicides significantly reduced the total yield of cranberries compared with unsprayed areas and also reduced the fruit rot later in storage. Zineb had the least detrimental effect on reduction of yields.

### C. Varietal Evaluation

1. Grape. The French-hybrid Seibel 12-375 appears to be widely adapted

under eastern U. S. conditions.

#### D. Culture and physiology

1. Grape. In California, production of grapes on rootstocks is becoming increasingly important. Shading Thompson and Emperor bench grafts after planting with the scion exposed resulted in slightly greater survival of the shaded grafts compared with unshaded. Emperor bench grafts have given consistently greater percentage of survival than Thompson grafts indicating a varietal difference in adaptability to bench grafting.
2. Strawberry. Gibberellic acid applied to newly set strawberry plants at Beltsville stimulated runner production on Earlidawn, Gem, and Geneva plants with blossoms; if the plants were deblossomed, gibberellic acid had no effect. Gibberellic acid applied to Pocahontas and Earlidawn plants in the fall of 1963 had no latent runner production stimulus on newly set plants taken from the sprayed plants in the spring of 1964. At Carbondale, Illinois, the cultural practice of mowing the tops of strawberry plants in July or August after the plants had fruited had no effect on yield the next year.
3. Blueberry. Blueberry plants propagated from hardwood cuttings that were 5 and 7 inches long made more top growth the first year in the propagation bed than from cuttings that were 1 and 3 inches long. There was no difference in the percentage rooting of cuttings that were 3, 4, and 6 inches long; but those 1 inch long rooted less than half that of longer cuttings.

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CITRUS AND SUBTROPICAL FRUIT CULTURE, BREEDING AND  
GENETICS, DISEASE INVESTIGATIONS AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. To maintain the position of prominence citrus holds in the health and diet of Americans, more information is needed on the factors which influence successful and economic production. More precise information is needed on the interrelation between climatic factors and growth, cold hardiness, and production; on the absorption processes and functions of various elements needed in growth and the effects of soil salinity, alkalinity, and high water retention on growth; on the biochemistry of citrus metabolism and the effects of air pollutants on metabolism and growth; on various diseases and methods to control them. New rootstocks are needed which induce more cold hardiness in tops; are disease and nematode tolerant; tolerant to high soil alkalinity, salinity, poor drainage; and which induce high yields of high quality fruit. New top varieties are needed with greater cold hardiness, greater disease resistance, better fruit quality, a wide spread in season of maturity, suitable both for fresh market and processing.

The United States has a humid subtropical zone extending from Charlestown, S.C., southward to the Florida Keys and westward to Corpus Christi, Texas, to which some varieties and kinds of subtropical fruits are potentially adapted. Other such fruits may be adapted to the irrigated regions extending from Corpus Christi southward to Brownsville and throughout the Lower Rio Grande Valley of Texas. Information is needed about the adaptation and culture of many tropical fruit plants which, in addition to their value as home fruit garden plants, may have commercial possibilities.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term research program involving plant pathologists, physiologists, horticulturists, and plant breeders carrying on both basic and applied studies to enable growers of dates, avocados, and citrus to increase both production and quality. Federal Stations having citrus and subtropical fruit research are Orlando, Florida; Weslaco, Texas; and Indio and Brawley, California. Date breeding, disease, and cultural research is done at Indio. Avocado disease and cultural research is done at Weslaco. Citrus research is done at the three Federal Stations. Citrus hybridizations are made at Orlando and Indio but not at Weslaco, and progenies are evaluated at all three locations; disease studies are carried on at all three Federal Stations; basic physiology studies of cold hardiness are centered at Weslaco, with variety and hybrid progenies evaluated for cold hardiness at all three Stations; rootstock evaluation on a field basis is centered in Florida, but preliminary evaluation of hybrid rootstock progenies and certain species for cold hardiness, salt tolerance, and disease resistance is carried on at all three Stations; basic nutrition is carried on principally in Florida but some work is also done in Texas and California. Climatology is carried on in Florida, Texas, Arizona, and in several

locations in California; the work in Arizona and California is in cooperation with the Agricultural Experiment Stations. Air pollution studies are carried on in California under contract with the University of California at Riverside.

The Federal scientific effort devoted to research in this area totals 18.0 man-years. Of this number 2.5 is devoted to breeding, 5.8 to diseases, 0.5 to variety evaluation, and 9.2 to culture.

Five 5-year PL 480 projects are currently in effect: (1) With the Instituto Biologica, Sao Paulo, Brazil, for studies on interference between strains of the tristeza virus (S3-CR-2); (2) with the Israel Ministry of Agriculture for studies on the physiological basis of tolerance of evergreen fruit trees to lime and saline soil and water conditions with special reference to the selection of rootstocks of avocado and citrus by physiological tests (A10-CR-7); (3) with the Israel Ministry of Agriculture, Rehovot, Israel, for studies of new methods for assessing nutrient status in citrus trees and other plants (A10-CR-36); (4) with the Indian Agricultural Research Institute, New Delhi, for studies on citrus dieback in India (A7-CR-3); and (5) with the Plant Virus Research Laboratory, Ministry of Agriculture, Cairo, Egypt, for citrus virus research (F4-CR-2).

#### PROGRAM OF STATE EXPERIMENT STATIONS

Six States and Puerto Rico have research on citrus and subtropical fruit. Cultural research on citrus includes investigations of rootstock and rootstock-scion relationships, response of citrus to spacing and pruning, response of citrus to soil management practices and irrigation, mineral nutrition, protecting citrus from cold injury, and determining the effects of salinity on citrus behavior. Other tropical and subtropical fruits receiving cultural research are avocados, pineapples, coffee, olives, figs, papayas, passion fruit, mangoes, and guava.

Citrus breeding or variety evaluation research is in progress in California, Florida, and Texas. Avocado breeding is in progress in California, Florida, and Puerto Rico. Texas and Louisiana are undertaking fig breeding or variety evaluation. Breeding of papayas, coffee, lychee, mango, guava, pineapple, and tea is being conducted at one, at least, or more locations.

Research on diseases of citrus is in progress in all States where this crop is grown. In three institutions, there is emphasis on the virus diseases of citrus. Leadership in this research is providing new knowledge on the detection, identification, and transmission of citrus viruses. Fundamental research on the nature of specific viruses, on virus synthesis and multiplication, and on the mechanism of resistance is contributing new scientific knowledge. Through several projects, Station scientists are learning more of the role of nematodes in citrus culture. Through basic studies on these nemas, specialized and highly effective methods of control, including biological, physical, and chemical, are being developed. A number of nema

problems are associated with other disease complexes in citrus, such as root rots. Fungus and bacterial diseases including fruit rots, wood necrosis, and root rots are being emphasized in the research of these scientists.

Diseases of avocado, pineapple, banana, coffee, dates, and palm nuts are also being studied at the stations. Bacterial and nematode diseases, re-plant problems, and fruit rots are of primary concern.

The total research effort on citrus and subtropical fruits at six States and Puerto Rico is approximately 15.4 professional man-years, of which 6.0 is for culture, 4.5 for breeding and variety evaluation, and 4.9 for disease investigations.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Breeding

1. Citrus. To produce new varieties including early-ripening grapefruit and cold-hardy, high quality orange, tangors, tangelos, and tangerines, 100 crosses were made. Approximately 25,000 hybrid seedlings from 1962 and 1963 crosses were planted at the citrus breeding farms in California, Texas, and Florida. Fifteen F<sub>1</sub> hybrids were selected and propagated for second testing at Indio, 3 hybrids were selected for possible release at Weslaco, and the Nova tangelo was released at Orlando. Nova (Orlando No. 426-9-22) originated from a cross of Clementine tangerine X Orlando tangelo (Citrus reticulata Blanco X (C. reticulata X C. paradisi Macf.)). Although the tree shows strong mandarin characteristics, the fruit has the same size and shape of the pollen parent, Orlando tangelo; consequently, Nova is classed as a tangelo. The fruit is earlier ripening, sweeter, and more highly colored than the Orlando tangelo. The fruit is of medium size, with a smooth orange-colored peel that is close fitting but is easily removed. It ripens in October and reaches its prime in November. The flesh is orange-colored, firm, and juicy. The flavor is pleasant and sweet. Nova is introduced because it ripens earlier, has better-colored peel, and has a more pleasant and sweeter flavor than Orlando tangelo. This variety has been tested only in Florida. It is recommended for trial plantings on a limited scale until it has been more widely evaluated.

### B. Diseases

#### 1. Citrus

a. Virus diseases. A rapid technique for testing the tristeza tolerance of rootstocks was perfected. Several severe isolates of tristeza were recovered from Meyer lemon trees, and one of these was transmitted by aphids from Meyer lemon to Mexican lime. Isolates of tatter leaf virus were also recovered from some of the Meyer lemon selections and were transmitted from Meyer lemon to cowpeas. In California, stubborn disease continues to

reduce yields of marketable fruit on affected trees. Seed abortion is closely associated with other stubborn symptoms. Stubborn is transmissible by grafting, and Madam Vinous sweet orange was found to be a promising indicator plant. Exocortis and stunt on trifoliate orange appear to be caused by the same virus.

PL 480 Research. United States-sponsored research in Brazil on interference between strains of tristeza virus (S3-CR-2) has shown that mild strains of the virus exist and that Galego lime is a better test plant than Para sweet orange or Ruby Red grapefruit. Greenhouse-grown seedlings infected through feeding of viruliferous aphids appears to be a better procedure than graft inoculation. Similarly sponsored research in Egypt on citrus virus diseases (F4-CR-2) confirmed earlier reports that xyloporosis was not seed transmitted and supports the use of seedlings for rootstocks without danger of transmitting xyloporosis. In India, PL 480 project on citrus dieback (A7-CR-3) showed that the disorder was due to tristeza.

b. Fungus diseases. The program of screening citrus hybrids and varieties for tolerance to *Phytophthora* is continuing by studies with the aerated water bath technique and by soil inoculations. The soil-inoculation technique is yielding data on the differential susceptibility of citrus varieties to *Phytophthora* spp. and *Thielaviopsis basicola*. *P. citrophthora* was identified from an isolate from roots in Florida for the first time. A species of *Physoderma* parasitic on citrus trees was described. The citrus *Physoderma* is systemic in the wood and bark. It was abnormally luxuriant in trees with symptoms of blight. Robinson tangerine dieback was obtained by artificial inoculation with *Diplodia*.

c. Spreading decline. Three burrowing nematode-tolerant rootstocks were jointly released by the USDA and the Florida Agricultural Experiment Station. Two new burrowing nematode-tolerant rootstocks have been found which carry cold hardiness character. One, the Yuma citrange, also has *Phytophthora* tolerance. The burrowing nematode has been successfully grown on alfalfa root callus in tissue culture.

#### C. Varietal evaluation

None

#### D. Culture and physiology

##### 1. Citrus

a. Rootstocks. The main long-term orchard experiments with rootstocks in Florida and Texas are still recovering from freeze damage of the 1962 freezes. Many new orchard tests with citrus rootstocks were initiated in Florida and Texas with the main emphasis on the evaluation of cold-hardy varieties and selections of rootstock hybrids from the breeding program at Indio.

b. Mineral nutrition. The main long-term field experiments with nutrition are still recovering from freeze damage of the 1962-63 winter, and no reliable and useful information was obtained.

PL 480 research in Israel on new methods for assessing nutrient status in citrus and other plants (A10-CR-36) indicates that nitrate reductase activity in citrus leaves is dependent on the molybdenum and N supply. Nitrite reduction also goes on and must be inhibited in order to measure nitrate reduction. No satisfactory inhibitors have yet been found. Other variables, such as leaf age, appear to be important.

c. Salt tolerance. Screening of hybrid seedlings of rootstock types was continued in 1964. Concentration of salts in the top foot of soil by evaporation had greater effect upon small than upon large plants. Combination salt and freeze treatment of Red Blush grapefruit trees indicates that where salt injury occurs the trees are unable to cold harden, even though weather conditions are favorable for hardening.

PL 480 research in Israel on the physiological basis of tolerance of evergreen fruit trees to lime and saline soil and water conditions (A10-CR-7) indicates certain advances in techniques such as the use of rooted and unrooted leaves for studies in the effect of Na on respiration, photosynthesis, and protein synthesis. The report further substantiates the greater salt tolerance of Cleopatra mandarin over sweet lime, the former probably being protected by an inhibitor which reduces Na uptake.

d. Cold hardiness. Cold hardiness investigations have been accelerated by additional personnel at Orlando where a study of trees injured in the 1962 freeze indicated a favorable recovery of most trees. At Weslaco, young hybrid trees from many crosses and young budded trees from many crosses and young budded trees on several rootstocks were screened for cold hardiness. Results were quite variable due to continuously changing weather which affected dormancy. Laboratory studies relating to the effects of various factors on the freezing point of leaves revealed that freezing points did not correlate well with the lethal temperature or with the hardiness of the leaves.

e. Citrus climatology. Environmental-physiological investigations are being advanced with the installation of an automatic meteorological station in Florida. Liquid petroleum gas heaters placed under small trees in Weslaco raised leaf temperatures 5 to 8°F. on cold nights. Solid paraffin-type fuel candles showed the good overall potential for raising the leaf temperature of small trees on cold nights in Florida.

f. Biochemistry. The early-ripening trait of the Robinson and Osceola tangerines is caused by a marked change in the metabolism of the fruit during late August and early September. The respiratory rate ( $O_2$  uptake) and cytochrome oxidase and peroxidase activity are high during this period and may be the cause of the rapid decrease in the citric acid content at that time.

## 2. Dates

- a. Fruit thinning. Erratic results were obtained from date fruit thinning tests with Elgetol because of severe injury to immature tissue at the base of fruit stalks. Thinning by removing fruit strands reduced yields in proportion to the amount of thinning and had little effect on size and grade of fruit.
- b. Nutrition. Annual fertilization of Khadrawy dates for 4 years with 0 to 8 pounds of nitrogen per tree affected growth slightly and yield not at all. This test was terminated with the 1964 harvest.

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TREE NUT CULTURE, BREEDING AND GENETICS,  
DISEASES, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. Tree nut production in the United States is much below the national consumption and needs to be materially increased. Production is limited by the need for better varieties that are more productive, disease resistant, of better quality, and less subject to spring frosts. More information is needed on nutritional requirements and the factors that induce biennial bearing. Diseases are often limiting factors and may even cause complete crop failure. Almonds are particularly subject to late frosts; later blooming varieties are feasible. Nut trees are known to have higher potassium requirements than the trees can absorb in heavy crop years. Methods of inducing increased absorption are needed. Tree nut crops have relatively low per acre production. New information is needed on tree spacing, dwarfing, rootstocks, and chemical fruit setters as well as more productive varieties to increase production per acre.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving breeders, plant pathologists, soil scientists, and horticulturists engaged in both basic studies and the application of known principles to the solution of growers' problems. Almond breeding research at Fresno, California, is cooperative with the California Experiment Station. Filbert breeding and cultural research at Corvallis, Oregon, is cooperative with the Oregon Experiment Station. Pecan breeding, variety evaluation, disease control and cultural studies at Meridian are cooperative with the Mississippi Experiment Station. Disease control and orchard management at Albany, Georgia; disease control, orchard management and nutrition at Shreveport, Louisiana; variety evaluation, orchard management and breeding at Brownwood are at Federally operated stations. Research on walnut diseases and culture at Corvallis, Oregon, is cooperative with the Oregon Experiment Station. Breeding research and variety evaluation (chestnuts, filberts and hicans) is carried on at Beltsville, Maryland.

The Federal scientific effort devoted to research in this area totals 13.7 professional man-years. Of this number 2.7 is devoted to breeding; 3.0 to diseases; 1.3 to variety evaluation; and 6.7 to culture.

PROGRAM OF STATE EXPERIMENT STATIONS

Cultural problems of the walnut, almond, filbert, and pecan are receiving attention at the State Stations. Alternate bearing is a major factor in pecan production, and several States in the South have projects dealing with various aspects of this subject. Soil moisture relationships and nutritional requirements of the pecan are also under investigation.

While there are a number of State stations testing tree nut varieties for local adaptation, only several States have active breeding projects. New Mexico is breeding pecans; New York is breeding filberts, and California is breeding almonds. Hawaii is testing and selecting Macadamia nuts for adaptation to the Islands.

Disease investigations include research on the aerial application of fungicides and the use of dormant eradicants for the control of pecan scab. Nematode research in relation to walnuts is continuing. Verticillium wilt of the almond and pistachio nut is receiving attention. Basic studies on selected pathogens are contributing fundamental knowledge of value in many areas of scientific investigation.

The total research effort on tree nuts at the State Stations is approximately 4.89 professional man-years, of which 2.91 is for culture, .73 for breeding and variety evaluation, and 1.25 for disease investigations.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding

1. Almond. Peach-almond hybrids developed by crossing almond with Nemaguard peach were more resistant to nematodes than the Nemaguard rootstock itself. Numerous hybrid seedlings are being evaluated for nut characteristics and nematode resistance.

2. Filbert. At Corvallis, Oregon, 196 varieties and selections were evaluated for kernel percentage and other desirable characteristics in a long-time program to develop superior new varieties.

3. Chinese chestnut. At Beltsville, Maryland, 2 dwarf, heavy-bearing Chinese chestnut selections are being used as germ-plasm to develop varieties with inherent smaller sized trees.

4. Walnut. At Corvallis, Oregon, Manregian walnut seedlings were hardier than the commonly grown Franquette variety. Selection work is being continued to develop a superior Manregian seedling that will replace Franquette.

5. Pecan. Samples of nuts from 1112 pecan seedlings from controlled crosses were harvested and evaluated. Of these, 170 were selected for propagation and further testing. Seventeen crosses were made in 1964 yielding 3196 hybrid nuts, and at least one parent in every cross was of Northern origin.

##### B. Diseases

1. Walnut. Walnut Blight (Bacteriosis). At Corvallis, Oregon, Bordeaux mixture 4-2-100 was the most effective material tested in controlling walnut bacteriosis.

Walnut trees grafted on Juglans hindsii are suspected of being subject to blackline disease although Franquette trees grafted on J. hindsii rootstocks in 1956 were reexamined, and no evidence of the disorder was found.

2. Pecan. Pecan scab. Under conditions of heavy rainfall, six applications of a new fungicide (DUTER-triphenyl tin hydroxide) 2-100 gave excellent control of pecan scab at Albany, Georgia. There were no phytotoxic results on 9 varieties at the strengths used.

Powdery mildew. Repeated tests showed that Karathene continued to be the most effective fungicide for controlling powdery mildew.

#### C. Variety evaluation

1. Pecan. The Elliott pecan was outstanding for good filling of nuts in 1964, when other varieties filled poorly. The Owens, a local variety in the Yazoo-Mississippi delta, is outstanding for regularity of bearing and resistance to pecan scab and bunch disease. It should be tested over a wider area.

2. Walnut. The nuts of forty-six varieties or selections were collected and systematically evaluated in a search for a new variety to replace Franquette. Hardiness tests are being continued at Hermiston, Oregon, where extremely low temperatures occur.

#### D. Culture and physiology

1. Filbert. Spacing tests. In tests at Wilsonville, Oregon, the greatest yield again was from the 15' X 15' planting. Trunk circumference measurements showed that trees planted 15' X 15' made the most growth, and the 25' X 25' spacing was next best.

Training. At Corvallis, Oregon, 5-year-old trees spaced 15' X 15' and trained to a single trunk yielded double that of bush-type trees, the same as last year.

Pollination. Fifty-eight percent of pistillate flowers set nut clusters following continuous rains during the 1964 pollination season at Corvallis, Oregon. This compares with 54.8 per cent in 1957, a heavy crop year, and indicates that rainy weather is not detrimental to successful pollination.

Nutrition studies. In Oregon, 16-16-16 fertilizer mixture gave the best yield with an increase of 1.96 pounds per tree over the check. Fertilizer treatments had no noticeable effect on quality of the nuts.

Growth regulators. At Beltsville, Maryland, applications of either 2,4,5-TP or B-9 (N-dimethyl amino succinamic acid) caused a one-third increase in filbert nut set (from 2 nuts per cluster to 3 nuts per cluster).

2. Pecan. Mineral nutrition. Applications of nitrate of potash as foliar sprays significantly increased the oil content of kernels at Albany, Georgia, but yield and percentage of kernel were not affected.

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POTATO CULTURE, BREEDING, DISEASES,  
AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. Potatoes are grown in all 50 States and are planted and harvested every month of the year, increasing the demand for varieties for regional adaptation and specialized uses and markets. Recent cultural practices necessitated by economic pressures for greater efficiency in production have tended to lower potato quality. Expanding research to reverse this trend is desirable. The rapid increase in potato processing has created a demand for new, more suitable varieties. The development of the food processing industry is one of the most dynamic of any phase of agriculture today. At least 50 products of various kinds are processed from potatoes. Basic information on genetic control of enzyme systems for developing potato varieties more suitable for processing is needed. Potentially valuable Solanum species and released varieties are not presently fully evaluated. To raise yields and potato quality beyond present levels requires new methods of breeding, more interspecific hybridization, and greater resistance to specific diseases. Potato diseases annually continue to cause significant losses at all levels of the industry. Information is needed on the nature of diseases and new methods of their control. Increasingly serious are stem-end browning, after-cooking darkening, and internal black spot. Causes and cures for these disorders are urgent. Genetic controls for insects and nematodes are needed to supplement and if possible replace chemical control.

USDA AND COOPERATIVE PROGRAM

Breeding, selecting, and testing of new varieties and seedlings for horticultural characters, storing, shipping, and culinary qualities and local adaptation are conducted cooperatively with the States at Presque Isle, Maine; Greeley, Colorado; Aberdeen, Idaho; Ames, Iowa; Baton Rouge, Louisiana; Ithaca, New York; Prosser, Washington; and Crystal City, Texas. In addition, testing of new seedlings is done at more than 25 additional locations in cooperation with State personnel.

Greenhouse crossing for production of true seed, for developing new varieties, and growing seedling tubers is done at Beltsville, Md., and to a lesser degree at Aberdeen, Baton Rouge, Prosser, and Greeley. Frost resistance is being developed in selections at Baton Rouge for winter crop production. At Aberdeen, Beltsville, Greeley, and Presque Isle, emphasis is placed on developing varieties adapted for processing. The development of insect-resistant lines is a major objective. In cooperation with the Rockefeller Institute at Mexico City, seedlings from Beltsville are evaluated for field resistance to severe late blight conditions of the Toluca Valley; significantly resistant varieties have been released.

Lines resistant to wind and heat are being developed in Texas with assistance of private cooperators. Parental lines and advance seedling selections that have resistance to sloughing off and that retain their opaqueness when diced, frozen, and reconstituted are being sought, also, through private cooperation, in Georgia, Maine, Maryland, New Jersey, Ohio, Pennsylvania, Texas, and Wisconsin.

The world collection of Solanum stocks is maintained at Sturgeon Bay, Wisconsin, at the Inter-Regional Potato Introduction Station. The production and study of Solanum tuberosum diploids (half the normal chromosome number) is done at Madison, Wisconsin, along with interspecific hybridization of diploids. At Beltsville investigations of crossability among Solanum species and meiosis of species and species hybrids are being conducted.

Disease controls are sought through breeding disease-resistant varieties and basic studies on the nature of specific diseases.

Scab resistance is a major breeding objective at all locations. The evaluation of progenies, seedling selections, and species for viruses X, A, and Y is done at Beltsville. Through State cooperators, seedlings from Beltsville are sent to Florida for determining corky-ringspot resistance, to New York for resistance to golden nematode, and to Ohio for insect-resistant characteristics. At Beltsville work is done on the development of techniques for evaluation tests of all major diseases with particular stress on leafroll and the viruses. Studies are underway to find improved methods of disease detection.

At Greeley, Colo., lines are developed that are resistant to scab and leafroll, and at Aberdeen, Idaho, and Prosser, Wash., to scab, leafroll, and Verticillium wilt. Early blight and Fusarium resistance tests are conducted at Aberdeen. At Baton Rouge, La., emphasis is placed on scab and late blight resistance, especially in red-skinned lines. At Presque Isle, Maine, disease evaluations are made for X, A, Y, leafroll, spindle tuber, ring rot, verticillium wilt, late and early blight, scab, and tuber necrosis. Disease control studies for late blight, scab, Verticillium wilt and viruses are likewise conducted in Maine. Internal black spot is a major consideration at our New York and Washington locations. Evaluation of breeding lines for resistance to golden nematode is done cooperatively at Ithaca, N.Y. Virus S is studied at Greeley.

The Federal program devoted to research in this area adds up to 14.2 professional man-years; 7.5 are assigned to breeding, 5.2 to diseases, 1.3 to culture, and 0.2 to variety evaluation.

Two 5-year PL 480 projects are currently in effect: (1) With the Polish Academy of Science, Krakow, Poland, for study of environmental factors affecting quality of tubers used for seed (E21-CR-24) providing funds with a \$48,548.83 equivalent in Polish zlotys and having a projected duration

from 1962 to 1967; (2) with the Estacion de Mejora de la Patata, Vitoria, Spain, to develop techniques for eradicating, inactivating, or curing potato tubers from their tuber-borne viruses (E25-CR-14) providing funds with a \$45,959 equivalent in Spanish pesetas and having a projected duration from 1963 to 1968.

#### PROGRAM OF THE STATE EXPERIMENT STATIONS

A number of State Stations are conducting research with potatoes designed to increase production under local conditions including nutritional studies, irrigation, and vine killing. Results are expressed in terms of yield, grade, and quality factors.

Potato breeding at the State Stations is closely cooperative with the National Potato Breeding Program of the Department. Breeding and variety evaluation projects are designed to produce varieties adapted to a given State or area. Selection criteria include yield; grade; quality of the processed product and cooking quality; shape; color; storage ability; earliness; resistance to heat, drought, and frost; and resistance to diseases such as the virus diseases of potato, ring rot, late blight, and scab.

The breeding program is strengthened by fundamental research in genetics and cytogenetics. The IR-1 (Interregional) project, Introduction, Preservation, Classification, Distribution, and Preliminary Evaluation of Wild and Cultivated Species of Solanum, is an invaluable aid to potato research. A new regional project, NC-84, Potato Genetics, cooperative among the States of the northcentral region and with ARS, was initiated during the year. This project will facilitate the use of newly developed potato haploids in genetic and breeding studies.

A wide range of basic studies on diseases of potato includes work on viruses, fungi, nematodes, bacteria, and also forecasting and detection work on late blight, nematodes, erticillium wilt, and certain viruses. Research on nematodes of potatoes has resulted in startling new knowledge on their relationship to soil bacterial populations, on the role of nemas in other diseases of potato, and much on the biochemical specifics of nema physiology. Leadership in this research is aided by four regional research projects on phytonematology.

Research on virus diseases has recently resulted in the isolation of genetic resistance to the spindle tuber virus, which may prove invaluable to plant breeders. Other viruses such as leafroll, X, Y, and numerous strains are receiving special attention. Immunity from virus Y and the mechanism of this response, the new findings on detection of virus RNA in plant cells infected with virus X, and antiserum for rattle virus are substantial contributions.

Resistance to Verticillium wilt, late blight, scab, Fusarium root rot, powdery scab, and Rhizoctonia blight is being developed through a number of well-coordinated research efforts. Bacterial diseases, such as ring rot, are receiving specialized attention in some studies.

The total research effort on potatoes at the State Stations is approximately 36.8 professional man-years, of which 9.9 is for culture, 17.4 for breeding and variety evaluation, and 9.5 for disease investigations.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Breeding

1. Potato Tuber-greening. Approximately 430 varieties and seedling selections were measured objectively and classified for intensity of greening in 1965. Twenty advance selections showed no visible greening (class 1). Seedling B5000-18 is an example of these greening-resistant selections which yielded 525 cwt. per acre of U.S. No. 1 tubers when grown in Maine.

2. Spindle Tuber. In cooperation with the Maine Experiment Station, several hundred seedlings are screened for resistance to spindle tuber virus each year. Seedlings B4876-4 and B1609-5 have survived reinoculations since 1961 and are still free from the spindle tuber virus.

3. Potato Cytogenetics. In cooperation with Wisconsin Experiment Station, problems related to ploidy and crossability in haploids of *S. tuberosum* L. and the tuber-bearing *Solanum* species were continued in 1964. From 660 haploids derived from 71 varieties or seedlings, 224 flowered sufficiently to be tested for female fertility; and only 114 shed sufficient pollen to permit testing for male fertility. In comparison to fifteen diploid F<sub>1</sub> clones of *S. phureja*-haploid matings with their vegetatively doubled counterparts in the greenhouse, the doubled clones set approximately half as much seed per fruit as the diploids. Also, in seedling families of crosses between diploid clones of *S. phureja* haploid hybrids and equivalent crosses between the tetraploid counterparts, the tetraploid seedlings grown from true seed were more vigorous and produced more and heavier tubers. Clones of diploid, tetraploid, and hexaploid species were grown for cytological and crossability studies at Beltsville. F<sub>1</sub> hybrid seed was obtained from 108 different interspecific pollinations among the diploids and from 3 matings among tetraploid and diploid species. F<sub>2</sub> seed was obtained from sib-matings in 48 of the diploid hybrid progenies.

4. Late Blight. Over 300 advanced seedlings were screened for late blight resistance at Toluca, Mexico, in cooperation with the Rockefeller Foundation and at Presque Isle, Maine, in cooperation with the Maine Agricultural Experiment Station. Many excellent blight-resistant seedlings were isolated.

Seedling B5281-1 is an example of a red, early-maturing selection that yielded 424 cwt. per acre of U.S. No. 1 tubers which were grown in Maine in 1965. It also showed resistance or immunity to tuber-greening, scab, golden nematode, and the mosaic viruses X, A, and Y.

5. Verticillium Wilt. In cooperation with the Maine Experiment Station, only 7 selections from over 300 tested in the field showed no wilt symptoms.

6. Leafroll. In cooperation with the Maine Experiment Station, only two seedlings out of 324 tested remained completely free of leafroll infection; B4808-3 is one of them. It also possesses resistance to scab, verticillium wilt, and virus Y.

7. Net Necrosis and Stem-end Browning. Tubers of 31 of the 53 selections tested expressed no symptoms of net necrosis or stem-end browning.

8. Golden Nematode. In cooperation with the New York Agricultural Experiment Station, 30 seedlings out of 82 tested were found resistant. Seedling B5036-40, an advance selection, is being increased because of its yielding ability and resistance to golden nematode and several other potato diseases.

9. Scab. In 1964, 10 seedlings out of 324 tested were found free of scab pustules. One of these, B5412-10, was an early maturing russet that had a relatively high rating in specific gravity, chipping quality, and late blight resistance.

10. Ring Rot. In cooperation with the Maine Agricultural Experiment Station, 20 out of 186 seedlings tested for ring rot resistance in 1963-1964 were found free of tuber symptoms. Resistant seedling B5000-18 is an increase since it also has high resistance to late blight and scab and is low in translucency and high firmness of potato dice.

11. Southern Region. In cooperation with the Louisiana Agricultural Experiment Station, several advanced seedlings showed promise, especially TL7935 and TL7627. Both seedlings performed well in the South and in the seed-producing areas of the northern States.

12. Colorado. In cooperation with the Agricultural Experiment Stations of Colorado and Wyoming, screening tests for disease resistance to both scab and verticillium wilt were conducted on approximately 200 seedlings. A limited screening method was designed to study the resistance in potato against Rhizoctonia solani, an old and troublesome tuber disease. Trends did develop.

13. Idaho. In cooperation with the Idaho Agricultural Experiment Station, 277 seedlings from 14,000 grown were saved for future evaluation. Progress was made in selecting promising seedlings that have resistance to scab and to Fusarium and Verticillium wilts. The oblong russet seedling A60120-1 yielded 222 cwt. per acre of U.S. No. 1 tubers compared to 130 cwt. for Russet Burbank, and it has good resistance to scab and Verticillium wilt.

14. Washington. In cooperation with the Washington Agricultural Experiment Station, 54 out of 35,000 seedlings grown in 1964 were selected for increase and evaluation in 1965. Seedling 48-1, a long russet type, has processing qualities, resistance to scab, leafroll, and Verticillium wilt, and yielded 635 cwt. per acre of U.S. No. 1 tubers.

15. Texas. In cooperation with the Texas Agricultural Experiment Station, yield and observational trials were conducted at 6 locations. Seedling BT4767-1R (red) and B5089-18 (white) yielded 282 and 212 cwt. U.S. No. 1 tubers per acre, respectively. The white selection is early maturing and is resistant to scab, late blight, and mild mosaic.

## B. Diseases

1. Potato Spindle Tuber Virus. Major emphasis has been placed on purification of the spindle tuber virus. Significant advances have been made in the past year. The virus has been concentrated to a level 1000 fold greater than that existing in infected plants.

A study of spindle tuber virus transmission through the true seed of potato has been initiated. Crosses involving infected and noninfected parent clones have been made, and presence of the virus in the seed has been established. Tests of the progeny from this seed are now in progress.

About 450 individual plants of 25 advanced selections were indexed for the presence of spindle tuber on a total of 1350 Rutgers tomato plants. An additional 12 clones were indexed for the Canadian Potato Breeding Program.

A comparative study with spindle tuber from Nebraska, reported to be caused by a strain of virus X, with spindle tuber from Maine was initiated.

2. Solanum Species Evaluation. The third year of testing 200 clones of various Solanum species for resistance to viruses X, Y, and leafroll was completed. Results were comparable to those of previous years. No special or outstanding resistance was detected in these tests.

3. Breeding Selection Evaluation. Approximately 324 advanced breeding selections were tested for resistance to viruses A, Y, and X and to late blight. All indexing for virus A was done in the greenhouse with the Solanum tuberosum x S. demissum hybrid "A-6" infected with a mild strain of virus X. Results were excellent with this indicator. Almost 60% of these selections were resistant to graft inoculation with virus A, and 94% were resistant to aphid inoculation. Only 54% of the selections were resistant to aphid inoculation with virus Y. Resistance to graft inoculation with virus X was present in 16% of the selections. Slightly more than half of the selections had one or more major genes for resistance to late blight, and 27% had 2 or more genes for resistance.

4. Control of Spread of Virus Y. Evidence from the previous year's test indicated that plants sprayed with an oil-water emulsion were not readily infected with viruses Y or A. In cooperation with the Entomology Research Division, a further trial was conducted on a larger scale. Results will be available for the next report.

5. Multigenic Field Resistance to Late Blight. An isolated plot was established in Maine for studies on multigenic resistance to late blight. This promising type of resistance is not broken down by specific races of the late blight fungus. A preliminary test of 57 clones selected for multigenic resistance resulted in 89% of the plants remaining free of blight throughout the season.

Public Law 480 Project. In Spain, attempts have been made to free potato seed-tubers of virus X and S and to determine the variability in virus estimations due to environment. One clone of Irish Cobbler has been isolated and appears to be free of virus X. Virus multiplication in potato plants was noted due to differences in nutrients, light, drought, and temperatures.

### C. Variety Evaluation

#### 1. New Releases

Monona, a USDA selection, was released in November because it possesses exceptional chipping qualities at harvest and after cold storage and conditioning. It also has moderate resistance to verticillium wilt and field resistance to viruses A and Y.

2. Outstanding Seedlings. Seedlings B4829-7, B5000-18, B5036-40, B5052-7, B5052-14, B5066-3, B5141-6, B5253-31, B5282-13, and B5287-5 are being increased in Maine as rapidly as possible for field tests to determine their suitability for commercial varieties. They are all relatively high in yielding ability and have good to excellent tuber appearance. Each seedling has one or more desirable processing qualities and multiple-disease resistance that includes resistance to two or more important potato diseases.

3. Potato Introductions. In cooperation with Plant Introduction Investigations of the New Crops Research Branch, 141 new stocks were received in 1964 from 11 countries (Argentina, Bolivia, Columbia, Ecuador, Germany, Japan, Mexico, Netherlands, Peru, Sweden, USSR). Seed of 202 introductions was sent to the National Seed Storage Laboratory, Fort Collins, Colorado. Shipments of 693 seed and 885 tuber samples were made to 18 States and 8 countries. Also, 116 new herbarium specimens of 20 species and 26 interspecific hybrids were made.

### D. Culture

1. Quality Evaluation of Seedlings and Varieties. Approximately 115 seedlings and varieties and 180 advance selections were compared for yielding ability, U.S. No. 1 grade percentages, specific gravity, and chipping

quality. Yields varied from 590 cwt. per acre of U.S. No. 1 tubers to 209 cwt. Specific gravity readings ranged from 1.057 to 1.095. B5042-2, a long white seedling, yielded 394 cwt. per acre, the same yield class as Katahdin, and had a 1.095 specific gravity reading. It is a good chipper and has resistance to several diseases. B5131-2 is an early maturing selection with excellent chipping qualities and multiple disease resistance as well as yielding ability. These selections and several others are on increase for further evaluation.

2. Cooperative Research. In cooperation with Campbell Soup Company in 1964, approximately 30 seedlings and varieties in replicated plots and 70 advance selections were grown at four locations (Maine, New Jersey, Ohio, and Wisconsin). This material was evaluated for yield, specific gravity, french frying, sloughing, and translucency before and after storage at various temperatures. Also, over 300 seedlings and varieties from other USDA plots were screened for use in frozen soups. Seedlings B4829-7, B5000-18, B5036-40, B5052-7, and B5066-3 are being increased for commercial purposes because of their ratings in firmness of dice and lowness of translucency.

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## SWEETPOTATO CULTURE, BREEDING, DISEASES, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. Acreage and per capita consumption of sweetpotatoes have declined for many years. Further decline in consumption per capita has been retarded by a trend toward use of processed products for which partial mechanization has caused some lowering in the per-unit costs of production. About one-third of the sweetpotato crop is processed. Production and handling of this crop requires much labor. Production of the crop, especially for the fresh market, has not been adequately mechanized; consequently, sweetpotatoes are becoming increasingly a luxury item on the fresh market. Yields per acre have been improved but still remain relatively low. Losses from diseases, including those caused by viruses, are high, and controls to date have not been generally applied effectively. New disease-resistant varieties of sweetpotatoes of high quality and suitability for processing, especially canning, and additional research on the nature and control of diseases are essential.

### USDA AND COOPERATIVE PROGRAM

The breeding program, utilizing selected parent stocks, has been continued at Beltsville in the search for better disease-resistant types suited to fresh market and processing requirements. The inherent and performance characteristics considered in the program are root shape and uniformity; appearance; size; set; skin and flesh colors; overall yielding capacity; and yields of desired grade classes for specific end uses, baking and processing quality properties, storability, propagative characteristics, general plant vigor, and growth habits; and adaptability to mechanized culture and handling procedures. Special attention is given to the development of selections possessing multiple-disease and pest resistance. Investigators in 20 States cooperate in the sweetpotato improvement program. Coordination of the overall cooperative improvement effort is handled at Beltsville, Md. Pathological studies and techniques for eliminating virus infections are conducted at Beltsville.

A program to develop better sweetpotato breeding parent lines is conducted at Tifton, Georgia, by Federal workers in cooperation with the Georgia Coastal Plain Experiment Station. Cytogenetic studies of Ipomoea species closely related to sweetpotatoes, intended to furnish a sound basis for subsequent basic studies on the genetics of the sweetpotato, are underway. Quantitative genetic studies are being undertaken on an interbreeding population from 19 selected parent clones of widely divergent backgrounds.

The Federal effort devoted to research in this area totals 4.0 professional man-years annually. Of this total 2.8 is devoted to breeding and genetics; and 1.2 to diseases.

#### PROGRAM OF THE STATE EXPERIMENT STATIONS

There is little cultural research directed specifically to the sweetpotato. There are numerous more general projects on the culture of vegetable crops, and work on sweetpotatoes is to be found under these when the occasion warrants such research. Cultural research with sweetpotatoes is concerned with fertilization, planting and harvesting dates, plant bed preparation, and weed control.

Nine States mainly in the Southeast have projects dealing with the breeding or variety evaluation of sweetpotatoes. Sweetpotato breeding is designed to develop varieties having superior yield under local conditions, of high market and nutritive value, possessing good processing characteristics, and resistant to diseases. Both fresh market and processed quality are determined by chemical techniques and taste panel scores. The breeding work is supplemented with research on genetics and cytogenetics.

Research on diseases of sweetpotatoes is pursued intensively through a well-coordinated program at the State Stations. Recent discoveries through this scientific effort on blister disease, russet crack, and internal cork virus are valuable contributions. Four research projects are directed toward providing knowledge essential to control of Fusarium oxysporum batatis. New findings in this research on differential mechanisms of resistance may provide a new tool in genetic and breeding studies. New insight into its variability and pathogenicity is also being obtained through one research project. Research is in progress on strains of the internal cork virus and on heat treatments for control of scurf; and chemical treatments for root rot, stem rot, and surface rot control offer much promise.

The total research effort on sweetpotatoes at the State Stations is approximately 13.3 professional man-years, of which 1.1 is for culture, 8.6 for breeding and varieties, and 3.6 for disease investigations.

#### PROGRESS--USDA AND COOPERATIVE PROGRAMS

##### A. Breeding

##### 1. Breeding Parent Development; Genetic and Cytogenetic Studies.

Intercrossing among 12 selections and introductions with known reactions to wilt, black rot, internal cork, and other diseases, is in progress in

the Tifton greenhouse. Resulting seedlings are being screened for resistance to diseases and nematodes, and their flowering potentials and meiotic behavior are being checked in the process of developing multiple-disease-resistant breeding parent stocks. Highly regular meiotic activity was found in cytological observations of 40 sweetpotato clones, indicating that the low seed set generally found in this plant must be due to causes other than meiotic abnormalities. A disease of pollen mother cells was observed and described and is believed to be a contributing cause in low seed set.

Studies on chromosome pairing and the consistent presence of secondary chromosomal associations in meiosis, indicate that at least two of the three genomes of the sweetpotato are closely related.

An interbreeding population of sweetpotatoes generated from 19 parent clones of widely diverse backgrounds has been developed through the second generation. Quantitative genetic studies will be initiated in the fourth such generation. As background information for interpretation of future genetic findings, 46 plant characters have been measured in studies of the variability existing in the parent clones and in seedlings in the first interbreeding cycle.

Interspecific crosses have been made successfully between I. batatas and I. pandurata and I. trifida, as well as among 9 wild *Ipomoea* species. F<sub>1</sub> seedlings of I. batatas x trifida have been successfully backcrossed to batatas. Some of the hybrids were highly fertile and bloomed prolifically. Repeated backcrossing may make it possible to transfer this high fertility characteristic to the sweetpotato.

#### B. Diseases

1. Fusarium Wilt. Freeze-drying of stock cultures of the wilt fungus was shown to be an effective way of preserving virulence for use in routine resistance evaluation tests.

2. Black Rot. Seedling B-7454, PI286621 from New Guinea, and Sunnyside were the most resistant of 27 selections inoculated with 3 virulent black rot cultures.

3. Tobacco Ringspot. In 1964 tobacco ringspot virus was isolated from one lot of Heartogold, maintained for several years at Beltsville.

4. Yellow Dwarf. In a comparison of methods for evaluating varietal susceptibility, 45% of 50 sweetpotato clones tested under field conditions became infected as a result of whitefly inoculation; 80% developed symptoms when the clones were graft-inoculated in the greenhouse.

5. Russet Crack. A heat-stable virus necrotic leaf spot symptom has been observed and found to be characteristic of this disease.

### C. Variety and Selection Evaluation

1. Regional Testing of Advanced Selections. NC-188 (Gem), L-8-3 (Julian), C-56-35, and L-9-89 had most satisfactory properties and all around performance characteristics in Regional Trials and are being tested further in 1965. Both Gem and Julian are weak plant producers. Gem showed excessive root cracking at Beltsville and some State Stations.

2. Testing of Advanced Beltsville Selections. Six of 24 advanced seedlings included in replicated trials exhibited good yielding, horticultural, and culinary properties. B7078 and B7186 are high yielding with a high proportion of canning size roots and have good baking and canning quality characteristics. B7078 has been entered in the 1965 Regional Observational trials.

3. Enzymatic Darkening Ratings. Forty-nine seedling selections, introductions, and varieties were rated. Among Regional test selections, there was relatively little darkening of flesh in L-9-89 and the Goldrush control but moderate to heavy discoloration in Gem, Julian, C-56-35, and the Centennial control. Severe discoloration occurred in 6 of 7 recent introductions from Peru and New Zealand. Darkening indexes were low in B seedling numbers 7124, 7427, 7431, 7452, 7453, and 7454, all of which are being observed further in 1965 field trials.

4. Foreign Introductions. PI286625 showed resistance to Fusarium wilt. PI286621 and PI286622 possess considerable resistance to black rot. These 3 lines are available at Tifton for the breeding parent development work.

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ONION, CARROT, AND OTHER ROOT AND BULB CROP CULTURE,  
BREEDING, DISEASES, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. The production of onions, carrots, garlic, shallots, leek, chives, and related crops is fairly well stabilized to adapted and highly specialized areas. Cultural requirements, methods, and practices vary widely from one location to another and need to be improved. Though the superiority of the  $F_1$  hybrid onion has been demonstrated, methods of seed production need to be improved. The principle of hybrid carrot seed production needs to be worked out. Further breeding is necessary to incorporate disease and insect resistance and other desirable horticultural characters into varieties suitable for specific purposes. Varieties are somewhat limited to regions of adaptation rather than area-wide. Increased research is needed on the pathology, physiology, and genetics of all these crops to facilitate improvement of the varieties and hybrids.

USDA AND COOPERATIVE PROGRAM

The Department research in this area is long-term and continuing. The primary objectives are to develop new and improved breeding lines, varieties, and hybrids of carrots and of onions that are disease- and insect-resistant, better than existing varieties and adapted for special uses. This work is being done by Federal personnel at Beltsville, Maryland; Greeley, Colorado; and Parma, Idaho. The personnel at Parma also develops information on cytology, genetics, statistical genetics, and problems relating to seed production. The nature and origin of cytoplasmic male sterility in both onions and carrots are under investigation at Beltsville. Genetic control of diseases and insects is a major objective at Beltsville and is done cooperatively with many State Experiment Stations and private seed and food-processing companies. Germ plasm from the same, and related species, is utilized in the improvement of both onion and carrot. Breeding of onions and carrots, including work on development and improvement of hybrids, using cytoplasmic male sterility, is done cooperatively at Madison, Wisconsin; Davis, California; Logan, Utah; Ithaca, New York; and Ames, Iowa. Studies on the nature and control of diseases of carrots are conducted at Weslaco, Texas, and research on onion diseases is being done through informal cooperation with several State and private agencies.

Four 5-year P.L. 480 projects are currently in effect: (1) E 21-CR-17, Studies on the epidemiology of onion downy mildew, Peronospora destructor, with the Institute of Soil Science and Cultivation, Skierniewice, Poland; (2) E 21-CR-31, Study of the causes of root greening in carrots, Institute of Plant Breeding, Wrablewkiego, Cracow, Poland; (3) A 10-CR-34, The nature and induction of cytoplasmic male sterility in plants with the National and University Institute of Agriculture, Rehovot, Israel; and (4) A 10-CR-14, Development of carotene bodies in the carrot root with The Hebrew University of Jerusalem, Jerusalem, Israel.

The Federal scientific effort devoted to research in this area totals 2.2 professional man-years, divided as follows: 2.0 breeding and genetics; 0.2 diseases.

#### PROGRAM OF STATE EXPERIMENT STATIONS

There are 60 general projects on the culture of vegetable crops on record from 31 States. Cultural research on onions, carrots, and other root and bulb crops is done under some of these projects when the need arises. There are only two projects which are specific for cultural research on this group of crops. One of these is in New York and is concerned with soil management for vegetables grown on muck soils; and one is in Texas and is concerned with fertilization, irrigation, and cultural practices for onions and carrots.

Sixteen projects are involved with the breeding or variety testing of root and bulb crops. Most of this work is concerned either with onions or carrots. The emphasis is on the production of hybrids with greater uniformity of size and shape, higher yields, quality, and disease resistance. The breeding work is strongly supported by genetic and cytogenetic investigations with considerable emphasis on the inheritance of male sterility. Much of the onion and carrot breeding work of the State Stations is cooperative with related research of the Department.

Other crops receiving breeding and genetic attention are turnips and table beets.

Research on diseases of onions, carrots, and similar crops is pursued at several of the State institutions. A number of mycoses such as those caused by Pyrenochaeta, Botrytis, and Sclerotium are being investigated. In one of these projects, investigations on the cellulolytic and pectolytic enzymes involved in fleck and blight disease of onions, are providing knowledge which will be of value in many areas of biology. Taxonomic study of the genus Botrytis and the relation of the two species on onion is a contribution of value. Study on sclerotial formation in the onion pathogen S. cepivorum is providing new concepts of this widespread function in fungi. Resistance to pink root and yellow dwarf resistance in shallots offer new promise for this select crop. Fumigants in onions are being studied, and indications of good disease control and large increases in yield offer much promise. The role of fungistasis and lysis in soilborne diseases is also being investigated. Portions of this research are coordinated through a regional research project on some of the mechanisms involved in soilborne disease.

The total research effort on onions, carrots, and other root and bulb crops at the State Stations is approximately 11.4 professional man-years, of which 2.7 is for culture, 6.1 for breeding and variety evaluation, and 2.6 for disease investigations.

PROGRESS -- USDA COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Short-day onions. Fifteen additional pink root-resistant strains of TEG 951 C and five strains of B 1410 C have been selected as conforming to type and must be tested for combining ability to be equal to, or surpassing, the regular strain in hybrid combination. Plant Introductions and *Allium* species are systematically checked for reaction to the pink root fungus at Crystal City, Texas. Several potential selections for dehydration produced satisfactory yields and had solids content of 18%-20%.
2. Thrips resistance. In cooperation with the Ohio Agricultural Experiment Station, thrips resistance has been found in B 3343, B 46-3140, B 58-814, B 58-812, and B 4131, all derivatives of crosses with White Persian, PI 86279. Thrips resistance has also been developed in the inbred, B 63-2816, which originated from a cross of *Allium cepa* by an unidentified *Allium* species. Likewise, B 59-2027, a cross between Yellow Sweet Spanish and Calred, has thrips resistance, downy mildew resistance, and pink root resistance in Texas and Oregon. B 61-501, B 61-502, B 61-511 and B 59-2000, all derived from an interspecific cross between *A. cepa* and *A. fistulosum*, show good thrips resistance. Some of the lines are nonglossy but thrips resistant.
3. Root types. Most of the inbreds segregate for long and short root systems at the Greeley Experiment Station. Some of the interspecific crosses produced excellent root systems.
4. Linkage testers. Thirty-five reciprocal translocation heterozygotes were isolated representing at least 10 separate occurrences of chromosome exchange caused by X-irradiation of seed. Translocation lines suitable as linkage testers are being developed from the irradiated material. Seed set on 22 triploids ranged from 0.4% to 4.0% of potential, whereas that of 14 comparable diploids ranged from 17% to 59%. Offspring of triploids will be screened for trisomics to develop lines suitable as linkage testers.
5. Amphidiploids. Fertile, apparently amphidiploid, plants have been successfully induced from the sterile interspecific hybrid between *Allium cepa* x *A. pskemense* and *A. cepa* x *A. galanthum* by colchicine treatment of topsets.
6. Bulb color. Hybrids between White Stockton Globe 36A and PI 211902 (both white selections) have colored bulbs, either all red, all yellow, or about half red and half yellow. This segregation of bulb color does not fit the usually accepted theory of three genes for color, but requires the postulation of either new dominance relations of the old alleles, or some new alleles at the same loci, or a fourth color locus.

7. Seed yields. Seed yields of inbred U 16-3-11 B varied from 100 to 928 seeds per umbel with a mean of 536 for a total of 75 umbels grown in a large cage in Colorado. Seed yields of inbreds grown in large cages in Beltsville also varied considerably. The inbred Ia 2997 B produced 700 seeds per plant as compared to 2219 for the inbred B 5546. Selected bulbs of two Oregon Yellow Danvers strains averaged 1916 seeds per plant. Eleven  $F_1$  hybrids produced 8.8 grams of seed per umbel as compared to 7.33 for 13 new inbreds, which had been inbred only one generation and 6.9 for four inbreds, which had been inbred two or more generations.

8. Species crosses. To date, the same gene causing male sterility in Allium cepa has been found in all the Allium species that will cross to either A. cepa or to A. fistulosum. The sterility barrier between any two of the mentioned species can be bridged by crossing to a third species. Allium cepa will cross to both A. galanthum and to A. pskemense to produce an  $F_1$ ; however, the  $F_1$  is highly female sterile and can, with difficulty, be backcrossed to A. cepa. Both A. galanthum and A. pskemense will cross to A. fistulosum and that  $F_1$  will cross readily to A. cepa. Generally the interspecific cross must be used as the male parent.

#### 9. Carrots

Specific gravity of carrot roots vary within variety as well as among varieties. Specific gravity is believed to be under the control of a number of genes. Specific gravity of the carrot root will affect the volume required to package a known weight. Hollow heart of carrot might be reduced through selection of roots with high specific gravity.

Two types of male sterility have been apparently induced in the progeny of fertile graft components grafted with cytoplasmic male-sterile components of Petunia: one exhibiting maternal inheritance (cytoplasmic) and one exhibiting monogenic recessive Mendelian male sterility.

The occurrence of chlorophyll a and b in greening roots of carrots has been confirmed. Hilling up decreased the greening grade of roots. Root greening occurs in all carrot tissue, but their inclination to it is not alike. Greening carrots have inferior technological properties and a lower commercial value.

Heritability of greening on the shoulders of carrot roots in one synthetic variety was estimated as  $23.5\% \pm 4.6$  when expressed as absolute vertical length of greening, and  $28.2\% \pm 6.6$  when expressed as a ratio of green length to total root length.

Root shapes of carrots are affected by plant populations. Some selections maintain the characteristic shape regardless of spacing; other strains have the characteristic variety shape only under some competition.

"Yellow foliage," a viable chlorophyll-deficient mutant, often found in the variety Waltham HiColor is easily recognized from seedling stage to maturity. A single homozygous recessive gene appears to be responsible.

## B. Diseases

1. Onion mildew. Six new host plants of onion downy mildew were found in Allium galanthum, A. flavum, A. ochroleucum, A. alataviense, A. alfidum, and A. tuberosum. Sporulation was greatest on A. flavum and least on A. tuberosum. No fungus infection was found on A. porrum.

New sources of downy mildew resistance have been found in PI 249903, PI 274254, PI 280553, Allium pskemense, A. galanthum, A. vavilovi, A. oschanini, U 16-3-11, P 54-306, and B 59-887.

2. Onion pink root. Onion lines screened for resistance to pink root in both Texas and Oregon had better root systems generally in the pink root nursery in Texas than lines resistant in only one area. The best resistance was found in a selected strain of Yellow Sweet Spanish. A number of short-day and long-day strains are being increased for release to the trade.

3. Alternaria of carrots. A selection of PI 226043 continued to show the highest level of resistance to Alternaria at Salisbury, Maryland. A selection of Royal Chantenay was the most susceptible to Alternaria and was affected even with a good spray program.

4. Aster yellows of carrots. Percentage of aster yellows in 40 breeding lines of carrots varied from 1.4 to 27.0. The incidence of the virus infection in varieties varied from 5.7 to 20.0. No line was free of the virus infection.

## C. Variety Evaluation and Physiology

1. Onions. Two hybrids, Ia 2578 x P 54-306, and Ia 2997 x P 54-306, were outstanding for direct seeding and for transplanting as a Spanish-type onion in Colorado. Parents of both hybrids are resistant to pink root in Texas and Oregon.

2. Hybrid carrots. Seed of hybrid carrots usually germinates faster, and emergence rate is higher than many open-pollinated carrots.

## PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

### Breeding

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PEAS AND BEAN CULTURE, BREEDING,  
DISEASES, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. Diseases are one of the most important obstacles to the economic production of beans and peas. Besides the usual ones such as the root rots, rust, anthracnose, curly top, and other virus diseases, of immediate concern is the bacterial halo blight disease which has appeared in some areas during the past 2 years in very destructive proportions. Since 85 percent of all snap bean seed produced in the United States is grown in southern Idaho where halo blight was noted during the past 2 years, extensive tests on overwintering of the organism, methods of control, and location of genes for resistance are being conducted. Further, the disease is not present in the Columbia Basin of Washington, but resistance to curly top is essential for safe production there; therefore, the development of multiple resistant varieties to this disease, mosaic, and Fusarium root rot is being given top priority so that some of the southern Idaho acreage can be transferred to the Columbia Basin when suitable varieties are developed. In addition to disease control, the greatest need of producers and consumers is more productive, widely adapted varieties with superior eating qualities, suitable for mechanized production and specific uses. Biological control of pests and diseases through breeding and other means (such as soil and crop management) is preferred to chemical methods when feasible. Since dry beans and peas are export items, in addition to disease-resistant types, breeders must search for and develop varieties with good storing and color qualities; the customers' desires abroad must also be considered. Efforts to develop stem anthracnose-resistant lima beans must continue. The edible cowpea or "southern pea" is becoming more popular nationally; and there is need to develop cultural, genetic, and pathologic information on this crop.

USDA AND COOPERATIVE PROGRAM

At Beltsville, Maryland, studies are conducted on breeding techniques and on the inheritance of resistance to certain diseases of snap beans and lima beans. Aid in evaluation of breeding materials in the several field locations is managed from here.

At Twin Falls, Idaho, and at Prosser, Washington (cooperative with the Idaho and Washington Agricultural Experiment Stations), applied breeding is conducted on dry beans for the West and on snap bean varieties grown both for food and seed purposes in the West. Major objectives are resistance to curly top virus and Fusarium root rot. Inheritance of resistance to curly top in both bean types is also being studied. Breeding of disease-resistant peas is conducted at Prosser and southern peas at Tifton, Georgia (cooperative with the Georgia Coastal Plain Experiment Station). Emphasis on peas

is on the development of disease-resistant stocks for variety synthesis by others. At Pullman, Washington, work is conducted on the development of superior lentil and dry pea varieties (cooperative with the Washington Agricultural Experiment Stations).

At East Lansing, Michigan (cooperative with the Michigan Agricultural Experiment Station), a well-rounded program of breeding and selection of disease-resistant dry beans is conducted for the humid dry bean districts of the United States, chiefly Michigan and New York.

At Charleston, South Carolina, disease-resistant snap beans are bred for adaptability to the Southeast for market and processing.

At Beltsville, Maryland, conventional pathologic studies on virus, fungus, and bacterial diseases and development of control measures are conducted on snap, dry, and lima beans, and peas. Similar studies on dry beans are conducted at East Lansing, Michigan, and on virus diseases of peas in the Northwest at Corvallis, Oregon (cooperative with the Oregon Agricultural Experiment Station). Work, mainly on fungus diseases of peas, is conducted at Prosser, Washington, and diseases of southern peas at Tifton, Georgia. The relationship of nematodes to root rot infection of beans is also being investigated at Prosser, Washington. Diseases of dry peas and lentils are investigated at Pullman, Washington. In Iran work was recently undertaken on the USDA/AID Regional Pulse Improvement Project.

The Federal scientific effort devoted to research in this area totals 12.0 professional man-years. Of this number 6.5 are devoted to breeding and genetics, 5.0 to disease, and 0.5 to variety evaluation.

#### PROGRAM OF STATE EXPERIMENT STATIONS

There are 60 general projects on the culture of vegetable crops on record from 31 States. Cultural research on peas and beans is done under some of these projects when the need arises. There are ten projects in seven States dealing specifically with the culture of peas and beans. These investigations include nutritional studies on southern peas, factors affecting quality of lima beans, fertilizer and tillage studies with dry beans, studies of flower and pod-drop in lima beans, and nutritional research with snap beans.

Forty-one projects in 21 States are concerned with the breeding or variety testing of peas and beans. Snap, field, and lima beans, peas, and southern peas all share in this research, which is aimed at development of varieties of local adaptation and greater consumer quality. Considerable emphasis is placed on developing southern peas and snap beans that are adapted to mechanical harvesting. Disease resistance is a prime consideration. The breeding programs are supplemented with genetic and cytogenetic studies.

Many diseases of beans cause direct field losses and severe depression of yields. Fusarium root rot is such a disease and is being studied through a well-coordinated regional research project. The nature of resistance, mechanisms of pathogenesis, amino acid metabolism of the fungus, variability in virulence and its cause are some areas under investigation. Interesting new relationships between a vascular fungus and a virus are being studied. The genetic basis for resistance to bean yellow mosaic virus, root rot, and anthracnose is being studied. New findings in cowpea viruses, such as the chlorotic mottle virus, which is not serologically related to the viruses of this crop, will aid in development of efficient controls. Root tip inoculation techniques have not been shown to be of real value in isolating genetic resistance to the Aphanomyces disease in peas. Nematode problems in peas are being investigated, and new techniques for work with these pathogens are being developed through this research. Chemical treatments for the control of lima bean root rot and anthracnose also offer much promise. Root and foliar feeding techniques are under study to control selected root rot.

The total research effort on peas and beans at the State Stations is approximately 25.4 professional man-years, of which 5.8 is for culture, 15.1 for breeding and variety evaluation, and 4.5 for disease investigations.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

###### 1. Dry Beans

a. Mosaic and anthracnose resistance. "Seaway 65" a selection from a cross incorporating mosaic and anthracnose resistance is ready for release to Michigan and New York growers. This variety is similar to Seaway (released in 1962), but it possesses more disease resistance than Seaway, including resistance to all of the important races of anthracnose as well as to common bean mosaic virus. It is also superior to Seaway in yield and processing qualities:

b. "Montcalm," a new Light Red Kidney type selected from a cross between California Light Red Kidney x Algarobo (a Colombia, South America, variety) is ready for release to Michigan and New York bean growers. It is resistant to the alpha, beta, and gamma races of anthracnose; matures earlier than the commercial Light Red Kidney; and has superior seed quality.

c. Curly top and mosaic resistance. In Washington from 6 mosaic- and curly top-resistant, early-maturing Red Mexican lines, Columbia Red Mexican #1 and #2 have been chosen for release in 1966. About 8,000 pounds of seed of each variety will be increased by growers in 1965.

d. The inheritance of resistance to a new virus resembling common bean mosaic virus (CBMV) in beans and of tolerance and resistance to curly top in existing snap bean varieties is being studied.

e. A number of promising Fusarium- and virus-resistant dry bean types with early short vine and strong bush habits adaptable to improved harvesting methods were made.

f. Crosses for virus-resistant El Salvador, C.A., types. Relative to the 2 bean disease and insect surveys made in El Salvador during the past year (in cooperation with the U.S. Agency for International Development), 75 crosses were made between Porillo No. 1 (a mosaic-resistant, black-seeded El Salvador type) and 8 American black- and red-seeded types (desired in El Salvador) in the greenhouse at Beltsville, Maryland. The F<sub>2</sub> seed is being produced at Beltsville and Prosser, Washington, and will be grown in El Salvador for selection of resistant types.

## 2. Snap Beans

a. Rust. Approximately 100 rust-resistant snap bean selections from F<sub>3</sub> and F<sub>4</sub> backcross populations adapted to eastern U.S. were made at Salisbury, Maryland.

b. Curly top. "Yakima," (formerly D 11), a curly top-resistant snap bean, was formally released jointly with the Washington and Idaho Stations. Primarily a home garden type, it also has processor and market garden potential. At Prosser, Washington, processor evaluations of 2 curly top-resistant wax lines indicate one may be ready for release in the next year or two.

Sixty-five advanced generation curly top-resistant, colored-seeded bulk selections were made from more than 380 lines selected in 1963. The white-seeded mutants (D 7) recovered from a diethyl sulfate-treated seed lot appear to be true mutants, and 20 single plant selections were made from them. About 30 selections were also made from 20 cross and backcross lines involving this mutant type.

c. At Charleston, South Carolina, over 200 selections were made from F<sub>2</sub> and F<sub>3</sub> progeny with firm pods having a thick exocarp and high flavor. About 60 crosses were made to study the inheritance of ruptured pericarp and flavor combinations with Blue Lake and Kentucky Wonder. Apparently the character associated with ruptured pericarp is recessive. Stronger bush type selections suitable for mechanical harvesting continue to show improvements; this especially includes selections where Phaseolus coccineus was used as a parent and backcrossed to several bush-type hybrids.

The new snap bean variety "Provider" (formerly B 3370) has been released to seedsmen. It is a very early type with high yield potential and wide adaptability and produces well in areas of the South where bean production formerly was not profitable.

### 3. Lima Beans

a. Downy mildew. At Beltsville, Maryland, 3 downy mildew-resistant, green-seeded Fordhook lines (U.S. 561, 861, and 1061) showed promise in commercial plantings in 1964. These lines will be tested more extensively in 1965 with the expectation of releasing one by 1967.

b. Two white-seeded, downy mildew-resistant, Fordhook lines (U.S. 261 and 761) showed promise in 1964 and will be tested commercially in 1965.

c. Two baby lima bean lines (G 1 and G 2) resistant to both strains of the downy mildew organism, were increased on a small scale in 1965. Fordhook lines resistant to these strains showed little promise.

### 4. Green Peas

a. Disease resistance. Over 200 selections and bulks were made from breeding lines possessing resistance to 7 of the most prevalent diseases of peas (bean yellow mosaic, wilt, near wilt, powdery mildew, streak, and Aphanomyces and Fusarium root rots).

### 5. Cowpeas

Only 2 breeding lines in more than 20 tested showed moderate resistance to the cowpea strain of tobacco mosaic virus. All plantings of the southern pea variety and breeding line observational trials were evaluated for resistance to the 7 most common diseases of cowpea.

### 6. Dry Peas and Lentils

a. Bleaching. More than 1,000 selections of nonbleached types of peas (the major quality problem in the Northwest) from lines chosen in 1963 and originally obtained from commercial seed companies and local growers were made.

b. Seed type. About 250 bulk lines of lentils originating from 1963 selections were harvested for evaluation of seed type (size, shape, and color) in 1964. Several thousand selections were also made from lines that showed promise in 1963. Several lines whose seeds measure 7 mm in diameter (desired by the trade) will be compared on a plot basis in 1965.

## 7. Legumes for Iran

Many P.I. lines and other varieties and strains of about 10 legumes were evaluated for disease and insect resistance, adaptability, potential yield, etc.; and many selections of the superior lines were made for 1965 planting.

### B. Diseases

#### 1. Beans and Lima Beans

a. Bean viruses. Differential susceptibility tests to the curly top virus in snap beans have pointed out the possibility of growing commercially tolerant varieties in the Columbia Basin.

In cooperation with the Washington State University, the red node virus has been purified and an antiserum produced. Two new bean and two new pea viruses are being purified and identified. A high titer antiserum for bean yellow mosaic virus was developed and is being used to study serological relationships between it and other bean viruses.

A new seedborne strain of common bean mosaic virus (CBMV) was isolated from a Mexican P.I. accession. This virus infects several important heretofore BV 1-resistant dry bean varieties grown in the U.S. Snap beans which carry the dominant resistance to the type CBMV are resistant to the new virus.

b. Bacterial diseases. A rapid reliable method using a needle puncture was devised to isolate the halo blight bacterium and other plant pathogenic bacteria. Of the 120 isolates made from bacterial infected beans received from different parts of the U.S. and examined during the past year, 60 were infected with the halo blight organism, 50 with the common blight organism, and 10 with the brown spot organism.

c. Fungus diseases. Anthracnose. The reaction of more than 40 domestic and European bean varieties to the 4 races of anthracnose showed no American variety resistant to the alpha race, one to the beta, but most were resistant to gamma. On the other hand, 2 European varieties resisted alpha, 6 beta, and 1 gamma. No commercial variety resisted delta. One white-seeded P.I. from El Salvador resisted all 4 races.

Ashy stem blight. Macrophomina phaseoli, the causal organism of ashy stem blight, was found to sporulate readily on propylene oxide-sterilized bean and cotton leaves.

d. Cultural controls. Plants 6 to 8 inches apart in the row had less root rot than those 2 to 4 inches apart. Seed yields were affected principally by row spacing. On Fusarium-infested land, reducing the row spacing from the conventional 22 inches to 14 or 7 inches, promoted thorough coverage

of the ground surface and increased seed yields significantly. On noninfested land, optimum ground cover and yields were obtained with the 22-inch row spacing.

Rate of plant growth was shown to be a vital factor affecting the degree of Fusarium root rot. Plants growing vigorously were only slightly affected, while plants restricted in growth were severely damaged. Evidently Fusarium damage is incidental to other factors which depress plant growth.

e. Chemical control. We controlled Fusarium root rot in the field when we applied Difolatan (50-100#/A) to the soil in vermiculite and worked it into the soil with a harrow to a depth of 4 inches. As compared to 3.4-4.1 for all other chemicals and the control Dithane (80% WP) at 80#/A, root-rot readings of 1.4-1.5 also appeared promising.

Lanstan (20% granular) applied at time of last cultivation appeared to reduce the severity of white mold or Sclerotinia wilt in beans in Michigan.

Slight infection of halo blight was noted in plots sprayed with Tribasic copper sulfate at 2 and 4#/100 gallons of water. Control plots were seriously infected.

## 2. Green Peas

a. Virus diseases. Three-year tests established that clover yellow mosaic virus, white clover mosaic virus, and bean yellow mosaic virus are transmitted in red clover seed. Cooperative studies with Brandes of Germany showed that an unknown virus from a seed lot with 17% infection had a rod length of 750 mμ and was serologically distinct from bean yellow mosaic virus.

Serological identifications indicated that the pea streak virus in eastern Washington and Oregon is related to the Wisconsin pea streak virus, while in western Oregon, streak peas were infected with red clover vein mosaic virus.

Studies on the effect of bean yellow mosaic virus on pod yield indicate that about 40% more pods are shed from infected than from healthy plants, and that the pods drop 2-4 days after petal fall. Pods that were developed beyond this stage did not absciss.

Pea streak virus was more prevalent in 1964 than in the 3 previous years. Field test results indicate that the later pea plants are infected, the more severe are pod symptoms. The rod-shaped viruses are gradually being categorized on basis of particle length with the electron microscope. This is being correlated with host range and serological studies and used to identify each isolate. Local lesion bioassay hosts indicate that only 50% as much virus exists in the roots as in the tops of pea plants infected with clover yellow mosaic virus. This is due to the fact that there is less normal plant protein, and no chlorophyll or other contaminating components to

interfere with virus purification. Therefore, it may still be advantageous to use root tissue instead of other plant tissue in purification studies. Our collection includes 35 lots of antisera specific to 12 different plant viruses.

### 3. Cowpeas

The effects of  $O_2$  and  $CO_2$  tension on growth of Fusarium oxysporum f. tracheiphilum showed  $O_2$  concentrations of 40% and above increased growth of fungus compared to growth in normal air. Concentrations of 20% and below reduced growth.  $CO_2$  concentrations of 5 to 60% reduced growth and inhibited it at 80%  $CO_2$ , but the mycelium was not killed, and growth resumed in 48 hours. These studies show that  $O_2$  tensions would not occur in the soil at levels low enough or  $CO_2$  concentrations high enough to be detrimental to the fungus. Flooding or incorporating green manure crops would have little effect in controlling this pathogen.

A cowpea virus observed in 1963 was identified as the cowpea strain of tobacco mosaic virus.

### 4. Dry Peas

In 1964 serious root rot damage to dry peas was noted. The fungi isolated were Aphanomyces euteiches, Ascochyta pisi, Fusarium, Rhizoctonia, and Sclerotinia spp.

A disease caused by an unidentified pathogen caused heavy losses to dry peas. The organism isolated consistently was a bacterium, but its pathogenicity has not yet been proven.

### 5. Lentils

Surveys substantiated by greenhouse tests showed that Fusarium oxysporum and Botrytis cineria caused damping-off and root rots. Also, Rhizoctonia spp., Sclerotinia sclerotiorum, Pythium sp., Verticillium albo-atrum, and Ascochyta pinodella were isolated from infected roots.

Greenhouse studies demonstrated that lentils are susceptible to the following pea viruses: Pea mottle, pea streak, pea enation, alfalfa mosaic, alfalfa yellow mosaic, and red clover vein mosaic viruses.

### C. Variety Evaluation and Physiology

Pod quality studies associated with flavor and firmness continued with increased emphasis on flavor. Wider crosses have been completed to supply segregating material to study improved methods of identification of the chemical characteristics of flavor. Chromatographic patterns from pole beans are not noticeably different from those of the bush types. Blue Lake and Kentucky Wonder produce similar patterns if older trifoliolate leaves are sampled. Seedling leaves and pods of these two varieties produce chromatographs showing distinct varietal differences.

### D. Culture

#### 1. Lima Beans

Germination and seedling vigor of lima beans is affected by pod maturity. The best germination and most vigorous seedlings were noted when seeds were harvested from mature, green, air-dried pods. Seeds of field-dried pods had the poorest germination with low seedling vigor. Seeds of green-seeded Fordhooks 561, 861, and 1061 with bleached cotyledons did not germinate as well as seeds having normal green cotyledons.

A new type 6x6-foot portable plastic hotbed and propagating frame resembling a miniature greenhouse was developed and has become very popular and useful to the home gardener.

#### 2. Dry Peas and Lentils

The effect of photoperiodism on seed production of lentils showed that in the P.I. lines from Chile that were studied, a period of 16 hours was required for flowering and pod production.

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TOMATO, PEPPER, AND RELATED CROP CULTURE,  
BREEDING, DISEASES, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. Shortage of labor to hand-harvest tomatoes, particularly for processing, is forcing drastic changes in many tomato improvement programs. Disease-resistant, prolific-fruited, small-vined varieties of high processing quality and possessing other qualities adapted to machine harvesting are needed now in the western, central, and eastern production areas. Serious diseases such as curly top, Verticillium wilt, leaf spots, and fruit rots are causing serious losses in certain areas in some years. Mechanization of the southern tomato and pepper transplant industry is dependent upon basic physiological studies on tomato and pepper seed dormancy and germination, seedling nutrition, and epidemiology of several plant bed disease-inducing organisms. Poor quality of tomatoes harvested mature-green continues to plague the consuming public. Lack of fruit firmness, crack resistance, fruit rot resistance, low pH, and high solids are major problems confronting the tomato processors.

Production problems of peppers are similar to those of the tomato, but the fruit quality problems are generally less troublesome.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving geneticists, plant pathologists, and horticulturists engaged in both basic studies and the application of known principles to growers' problems. Tomato breeding and genetic studies at Beltsville, Maryland, involve crossing progeny selection, disease evaluation, and horticultural selection for adaptability to mechanical harvesting and superior quality. At Charleston, South Carolina, breeding for adaptability to southeastern conditions is stressed; while at Logan, Utah, the prime purpose is development of genetic resistance to the curly top disease. At Cheyenne, Wyoming, breeding is directed toward adaptability to the temperature extremes and low humidity of the Great Plains. Disease studies on early blight, bacterial spot, gray leaf spot, Fusarium wilt, Verticillium wilt, and tobacco mosaic virus are conducted in controlled laboratory and field experiments at Beltsville, Maryland. Disease research at Tifton, Georgia, includes bacterial spot; early blight; gray leaf spot; and southern blight of tomato, pepper, and similar vegetable transplants. At Prosser, Washington, work is concentrated upon identities of the variations in strains of the curly top virus. Limited varietal evaluation is conducted at Beltsville, Maryland; Tifton, Georgia; Logan, Utah; and Prosser, Washington. Work on culture and nutrition of tomato and pepper plants is conducted at Tifton, Georgia.

The Federal scientific effort devoted to research in this area totals 10 professional man-years. Of this number 4.8 are devoted to breeding and genetics, 4.2 to disease, and 1.0 to culture.

#### PROGRAM OF STATE EXPERIMENT STATIONS

There are 60 general projects on the culture of vegetable crops on record from 31 States. Cultural research on tomatoes, peppers, and related crops is done under some of these projects when the need arises. Dealing specifically with the culture of tomatoes, peppers, and related crops are 17 projects in nine States. The bulk of these projects are concerned with tomatoes. Research includes studies of the nutritional requirements of both field-grown and greenhouse tomatoes, effect of growth regulators on fruit set, influence of light intensity and temperature on development of greenhouse tomatoes, cultural requirements of tomatoes in plastic houses, effect of supplemental CO<sub>2</sub> in greenhouse production, plant growing methods, and studies of the physiology of ripening of the tomato. Research with peppers includes studies of spacing and fertilizer requirements for Bell and Pimento peppers and pepper plant growing methods.

Tomato and pepper breeding is in progress under 44 projects in 26 States. Tomato breeding is concerned with both fresh market and processing types. Currently, considerable emphasis is placed on developing tomato varieties for processing that are adapted to mechanical harvesting. Disease and nematode resistance are emphasized along with quality for either fresh market or processing. Various types of peppers are receiving breeding attention, including sweet, pungent, pimento, and chile. Considerable fundamental genetic research is done employing the tomato as a tool. Breeding of tomatoes throughout much of the country is coordinated through the STEP trials of the Southern States and USDA.

Genetic research is coordinated through the activities of the Tomato Genetics Cooperative.

Scientists at the State Stations are providing leadership through a number of research projects on the diseases of tomato and related crops. In some cases, these involve fundamental studies on viruses, such as synthesis, multiplication, mode of action, and the biochemical specifics of resistance. Others are concerned with nuclear phenomenon and nucleic acid synthesis in selected tomato pathogens such as the early blight organisms. Work on bacterial agents of pepper and tomato diseases, such as P. solanacearum, is providing new concepts of value in control of many bacteria, as well as providing new findings on strains affecting tomato that can be serologically and biochemically defined. Research on the use of viruses (phages) to establish strain and pathogenicity patents is of much value. New types of genetic resistance to virus and nematodes in pepper offer great promise. Radiological techniques are being used to isolate efficient sources of mosaic resistance. Leaf spot and blotchy disease resistance has been located through careful investigations, and the ability to differentiate mosaic strains for use in breeding studies is a valuable contribution.

Bacterial spot in pepper and seedborne bacterial diseases of tomato are receiving special attention. Refined and efficient chemical controls for pepper and tomato diseases are being developed through research at some locations.

The total research effort on tomatoes, peppers, and related crops at the State Stations is approximately 45.1 professional man-years of which 6.6 is for culture, 24.6 for breeding and variety evaluation, and 13.9 for disease investigations.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Breeding and Genetics

#### 1. Tomatoes

a. Selection for fruit quality characteristics from multiple disease-resistant germplasm. Continuous attention is given at Beltsville, Maryland, to fruit quality and disease resistance. PH, titratable acidity, solids, color, and firmness measurements were made on fruit of more than 1800 single plant selections from multiple disease-resistant lines. Numerous low pH, high-solid lines with other high quality characteristics were selected for breeding and further study. Comparative greenhouse and field studies on 445 F<sub>2</sub> plants from 11 parental combinations indicate that selection for high soluble solid content of tomato can be done in the greenhouse, thus adding an extra generation of selection for this quality characteristic each year.

Cooperative studies with the Agricultural Marketing Service and Food Quality Laboratory, ARS, showed that 2 breeding lines, 63B572 and 63B755, were superior in color, high acidity, and flavor to 2 other lines and 2 standard varieties 4 1/2 months after processing. Studies cooperative with Human Nutrition Laboratory were made on raw fruit characteristics of 6 tomato varieties and related to taste panel results. These studies and interpretation of results will continue.

At Charleston, South Carolina, the vacuum immersion method for measuring crack resistance in tomato fruit is being utilized under laboratory conditions for precision measurements of this character to enhance levels of crack resistance in breeding stocks and lines. At Charleston the mutant color types, Crimson and High Pigment (hphp), are being utilized in the improvement of color in artificially ripened fruit. Studies are in progress to establish the genetic basis for the Crimson character and the nature of gene action.

b. Variety Evaluation and Physiology. B-96, an early, determinate multiple disease-resistant, crack-resistant tomato line has performed so well the past 3 years, it will be released to the seed trade in 1965. Of the 14 paste lines grown in Maryland, New Jersey, and Colorado in 1964, 4 have been selected for national trials. Three of 4 multiple

disease-resistant, high-fruit quality tomatoes submitted from Beltsville, Maryland, to the STEP regional trials 63B481, 63B752, and 63B739, ranked second, third, and fourth, respectively of 22 lines and varieties included in the trials at Beltsville.

At Charleston, South Carolina, VBL STEP 397 has been rated high in the STEP trials for the past 3 years and is being considered for release. Grower trials have been established for the 1965 season and plantings made for the initial seed increase.

c. Breeding tomatoes for the High Plains. Adaptability trials of multiple disease-resistant tomato lines were planted at Cheyenne, Wyoming; Fort Lupton, Colorado; and Greeley, Colorado. PH, soluble solid and fruit color measurements were made on 150 single plant selections from these trials.

d. Verticillium and Fusarium. At Beltsville, Maryland; Cheyenne, Wyoming; and Logan, Utah, large-scale screening trials and crossing programs were conducted in order to incorporate dual wilt resistance into adapted breeding stocks with good fruit quality possessing resistance to other major diseases, such as curly top, gray leaf spot, and bacterial canker.

e. Breeding systems in tomato. At Charleston, South Carolina, and Beltsville, Maryland, studies on breeding systems are continuing. Modifications of inbreeding procedures ranging from strict inbreeding by selfing to continuous sib-crossing in each line are in progress to determine their relative merit where selection for quantitative characters are desired. To date, the practice of mass selection followed by sib-crossing appears to be an effective system of tomato breeding, based on line performance in the STEP trials.

f. Inheritance of resistance to tobacco mosaic virus (TMV).  $F_1$ ,  $F_2$ , and reciprocal backcross progenies were studied for segregation of resistance to TMV.  $F_2$  data indicate a single gene pair conditions resistance. Back-cross data, however, indicate additional factors may be involved.

## B. Diseases

### 1. Tomatoes

a. Identification of causal agent of disease through serology. At Tifton, Georgia, an antiserum was developed that is specific to the bacterial wilt organism (Pseudomonas solanacearum). This organism has a wide host range among cultivated crops and native weeds. This technique will aid in epidemiological studies of this organism on numerous crops.

b. Black shoulder of mature-green tomato fruit. At Tifton, Georgia, a disease of mature-green tomato fruit was shown to be caused by initial physiological disturbances followed by infection with Aspergillus tenuis.

## C. Culture

### 1. Tomato and pepper.

a. Nutrition. At Tifton, Georgia, studies with tomato and pepper seedlings grown as transplants for northern production areas continue to show that yields of transplants per acre are more than tripled when proper fertilization, seeding, and irrigation practices are followed. Under optimum nutritional practices, approximately 75 percent of the plants were marketable. Additional nutritional and seed germination studies are underway to obtain at least 90 percent marketable plants per acre to enable mechanization of the industry.

At Tifton, Georgia, the relative merits of 11 nitrogen sources or combination of sources were evaluated at 2 seeding dates on two major soil types. Cotton seed meal, diammonium phosphate, and ammonium sulfate produced the most marketable plants per acre in the early seeded plots. Diammonium phosphate was the superior nitrogen source in the late seeded plots.

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## MUSKMELON, OTHER CUCURBITS AND LEAFY VEGETABLES

Crops Research Division, ARS

Problem. Major problems of muskmelons and related crops are poor yields and quality caused by lack of adapted varieties resistant to diseases. Diseases such as powdery and downy mildew, cucumber mosaic, watermelon mosaic viruses 1 and 2, tobacco ringspot, gummy stem blight, anthracnose, scab and others seriously reduce yields and impair fruit quality in some regions of production each year. Crown blight of muskmelons, a disease complex of the Southwest, is not yet controlled. Cucurbits, particularly muskmelons and cucumbers, adapted to machine harvesting are needed to reduce production costs. Potentials of  $F_1$  hybrids and methods of their production needs extensive study. Improvements in breeding methods are needed to increase the efficiency of breeding programs.

The main problems of the lettuce grower are currently centered around mechanization of crop production. Varieties are needed that will emerge, develop and mature uniformly in order to make efficient use of mechanical equipment in such cultural operations as land preparation, fertilization, irrigation, weed control, thinning, and in particular, harvesting. Disease problems, for example, tipburn, big vein, rib discoloration, downy mildew, and lettuce mosaic are mostly uncontrolled or at best only partially controlled. These diseases are a chronic hazard to profitable production. In spinach, further work is essential to produce adapted high quality, productive hybrid varieties, resistant to disease and amenable to processing.

### USDA AND COOPERATIVE PROGRAMS

The Department has a continuing long-term program involving geneticists, horticulturists, and plant pathologists engaged in both basic and applied research on melons, other cucurbits and lettuce and related crops. Extensive muskmelon and squash breeding and genetic studies are conducted at La Jolla and Brawley, California; Charleston, South Carolina; and Beltsville, Maryland. Watermelon breeding is done at Charleston. Disease research with emphasis on crown blight of muskmelons is done at Beltsville, Maryland, and Mesa and Tucson, Arizona, in cooperation with the Arizona Agricultural Experiment Station.

Work on lettuce is conducted at La Jolla, Brawley and Salinas, California, and Weslaco, Texas. The research at La Jolla and Brawley is designed to develop disease resistant varieties adapted to the Southwest. The effort at Salinas is directed mainly toward a search for resistance to lettuce mosaic and big vein, the production of  $F_1$  hybrids through the use of male steriles; also genetic studies. At Weslaco, the objective is to develop varieties resistant to downy mildew and adapted to culture in the Lower Rio Grande Valley. At Beltsville, Maryland, spinach research is done to

improve breeding techniques and methods of hybrid seed production. Varieties and hybrids adapted to different areas of production and resistant to white rust, mosaic, and other diseases are being developed.

The Federal scientific effort devoted to research on melons and other cucurbits totals 4.6 professional man-years. Of this number, 2.7 are devoted to breeding and genetics, 1.4 to diseases, and .5 to variety evaluation. A total of 2.5 professional man-years is devoted to research on breeding and genetics on lettuce and other leafy vegetables.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Cultural research with cucurbits at the State Stations involves investigations of fertility and irrigation needs in relation to local environmental conditions. Fertility research is correlated with chemical tissue tests and soil analyses. Emphasis is placed upon increased yields and quality of the fruit. Four projects in four States deal specifically with the cultural needs of watermelons, cantaloupes, and cucumbers. Besides these projects there are 60 cultural projects of a general nature at 31 States designed to ascertain most effective cultural methods for vegetables in relation to local environmental conditions.

Considerable effort is made by the States to develop superior cucurbits possessing adaptation to local conditions. Watermelons, cantaloupes, muskmelons, cucumbers for pickles and fresh market, and squash receive attention. There is interest in the possibility of F<sub>1</sub> hybrids and in the "bush" character to facilitate mechanical harvesting. Emphasis is placed on quality of the fruit. The breeding work is supported by genetic and cytogenetic investigations. There are 26 active projects specifically on the breeding of cucurbits in 16 States.

Research on Verticillium wilt in Cucumis melo is designed to isolate sources of resistance to this disease, which can be used effectively in breeding work. In addition, research on chemical control of this disease also offers promise. State Station scientists are concerned with many other disease problems in melons and other cucurbits. Histological investigations on gummy stem blight in watermelon have provided new information on seed infection which will aid in control of this disease. Other scientists have developed antisera for strains of wild cucumber mosaic virus which will be a valuable tool in detection and identification of these viruses. Studies on desert plants have shown recently that common species of Erodium are carriers of watermelon mosaic virus, which also causes poor set and small, deformed fruit in cantaloup. Such research may lead to efficient control of this destructive virus. Sources of resistance to cucumber scab, cantaloup scab, and pumpkin powdery mildew are being sought through several research projects. The biochemical basis for virulence in the cucumber anthracnose fungus is being studied in two projects. Information gained

from these projects will be valuable in helping to provide control for this disease. A number of scientists are studying nematode problems in cucurbit culture. Recent findings in studies on root-knot nema of muskmelon indicate that the primary effect of these causal agents may be on the metabolism of the plant, rather than an immediate effect on uptake or translocation of minerals. Progress in this research affords an opportunity to contribute new knowledge which will eventually be of use in solving many nematode problems.

The total research effort on melons and other cucurbits at the State Stations is approximately 22.5 professional man-years, of which 2.2 is for culture, 13.3 for breeding and variety evaluation, and 7.0 for disease investigations.

Research on the culture of leafy vegetables is involved in 10 projects in eight States. Lettuce research includes cultural studies of irrigation levels and frequency, fertilizer rates and methods of application, and the effect of environmental factors on pink rib. Other research includes a study of nutrient intensity on growth, yield, and quality of cauliflower; plant growing practices, plant spacing, and nutrition of broccoli; cultural control of pencil stripe in celery; fertilization of cabbage; and methods of growing spinach and other greens. Besides this research, there are 60 general projects on culture of vegetable crops on record from 31 States.

Eighteen projects in 11 States are involved in the breeding of leafy vegetable crops. Crops receiving attention are lettuce, cabbage, cauliflower, broccoli, collards, celery, spinach, and cress. Lettuce breeding is aimed at incorporating resistance to tipburn, downy mildew, and big vein; heat tolerance; and desirable size into high quality lettuce adapted to local conditions. Cabbage breeding is concerned with incorporating resistance to diseases such as yellows, clubroot, blackrot, and downy mildew into locally adapted slow-bolting varieties showing tolerance to both heat and cold. Some emphasis with crucifer breeding is directed toward development of  $F_1$  hybrids. Celery breeding is concerned with resistance to *Cercospora*. Spinach breeding is aimed at development of varieties or hybrids that are resistant to disease and are acceptable for canning, freezing, and fresh market.

Breeding research with leafy vegetables is supplemented and supported by genetic and cytogenetic investigations.

Research on diseases of leafy vegetables is variable in nature due to the range in crop varieties, culture conditions, and pathogenic agents involved. Some research projects are designed to provide information on the chemical control of diseases such as downy mildew in broccoli; clubroot in cabbage, root rot in lettuce, and rust in spinach. Techniques for the isolation of resistant germplasm to aid in control of these diseases are being developed at a few State Stations. Leadership in basic research on viruses and virus transmission resulted in the startling new discovery of the transmission of virus (big vein lettuce) by the spores

of an aquatic fungus (*Olpidium*), and thus provided new concepts on virus activity. Research in this area is continuing with studies on virus retention, multiplication, and the role of resting spores. New knowledge on obligate parasitism is being gained through histological and histochemical studies of downy mildew of lettuce. Tissue culture techniques used in this work will also be of value in other areas of science. Research on the mechanism of root rot resistance in lettuce may do much to solve this pressing disease problem.

The total research effort on leafy vegetables at the State Stations is approximately 31.2 professional man-years; of which 7.9 is for culture, 19.4 for breeding and variety evaluation, and 3.9 for disease investigations.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

###### 1. Muskmelons

a. Breeding for multiple disease resistance. In cooperation with California, Arizona, and Texas Agricultural Experiment Stations, powdery mildew-crown blight-resistant breeding lines, from the cross  $P_3 \times 45 \times 450_3$ , were evaluated in experimental and grower's fields at Brawley, El Centro, Imperial, Blythe, Davis, and Five Points, California; at Yuma and Mesa, Arizona; and at Weslaco, Rio Grande City, and Crystal City, Texas. Similar lines of Honey Dew were evaluated at several of these locations.

Forty multiple disease-resistant breeding stocks were advanced two generations by alternate mass selection and enforced sib-crossing; one of these performed well in the southern regional trials and is now in commercial tests.

b. Variety release. The cantaloup selection, 43725-M4, a high quality, productive PMR 450 type with greater resistance to powdery mildew and crown blight than PMR 450 was released to the seed trade as "Jacumba".

c. Watermelon mosaic-resistance. Breeding lines with watermelon mosaic-resistance from the crosses Jacumba  $\times$  WMR 90105 and Campo  $\times$  WMR 90105 were carried to the fifth and sixth successive backcrosses at La Jolla. More than 100  $B_2$  and  $B_3$  progenies were evaluated in the field at Brawley and Blythe, California; and at Mesa, Arizona. Similar programs were conducted with male-sterile cantaloups and with PMR Honey Dew. Similar work was conducted at Beltsville using eastern and southern varieties as recurrent parents.

d. Cucumber mosaic-resistance. The delayed backcross was utilized with controlled tests at La Jolla, California, and Beltsville, Maryland, to transfer cucumber mosaic resistance, dependent on two recessive factors,

into PMR cantaloup and PMR Honey Dew. Breeding material with combined resistance to powdery mildew, crown blight, watermelon mosaic resistance, and cucumber mosaic resistance has been obtained.

e. Resistance to nematodes. At Charleston, South Carolina, in cooperation with nematologists, intensive efforts were made to cross Cucumis melo with certain wild species of Cucumis that have resistance to nematodes. Many interspecific crosses were successful, and subsequent crosses of C. melo into the hybrids were partially successful.

f. Development of breeding methods. At Charleston, South Carolina, and La Jolla, California, continued emphasis is placed on overall performance rather than on superiority in individual traits of muskmelon populations; hence, selection is based on an index derived from compilation of 16 characteristics. Preliminary calculations of one completed experiment show that certain characters (such as stem scar) have undergone a favorable shift in population means during 9 generations of mass selection even though no selection pressure was applied to those specific characters. Other characters (such as ascorbic acid content) failed to shift favorably. Preliminary data also suggest that inbreds extracted from mass generations 6 to 9 perform better than inbreds extracted from mass generations 1 to 5.

g. Experimental morphogenesis in cucurbits. In cooperation with Israel (P.L. 480 A10-CR-49), studies were initiated to study factors controlling six differentiations in cucumber and muskmelon. Studies were made to determine the most favorable artificial culture medium on which to grow excised flower buds to study the effects of auxins and antiauxins on sex expression. An autoradiographic method for tracing the distribution in cucumber plants of applied IAA-C<sup>14</sup> was developed. It was found there is an obvious polaric movement of auxin - from the IAA-treated leaf down toward the root.

h. Genetics and cytogenetics. Linkage tests of seedling and young plant markers were continued at La Jolla, California, and Mesa, Arizona, in the search for an easily recognized marker linked with male-sterile 1 and male-sterile 2. A suitable marker would facilitate the commercial production of F<sub>1</sub> hybrid seed. A new marker, red stem, was found in P. I. 157083. It segregates as a unit factor in hybrid progenies.

Work at La Jolla and at Davis, California, indicate that the accessions Hardin's Bush and Big River Bush have the same genetic factor for the bush character. This character may be valuable in breeding for mechanical harvesting.

## 2. Squash

a. Interspecific hybridization. From a series of interspecific hybridizations and appropriate backcrosses involving Cucurbita lundelliana, a wild species, and the cultivated species C. maxima and C. moschata,

several stable squash lines have been isolated. These lines have a high degree of resistance to powdery mildew. They are being evaluated for horticultural characteristics and consumer qualities.

### 3. Watermelon

a. Tetraploids and triploids. Nine experimental tetraploids with improved quality and productivity were advanced another generation under mass selection. Extra genome effects were demonstrated in the form of greater resistance to *Fusarium* wilt. Stocks of 15 experimental triploid hybrids were increased; several of these produced high quality seedless melons. Stocks of 15 experimental  $F_1$  (diploid) hybrids likewise were increased; one of these rated high in 1964 regional trials. The greatest heterotic effects in triploids appeared when small early varieties were crossed with large late varieties; size and shape characteristics tend to be intermediate in the hybrid, while earliness tends to be dominant. One standard type large-fruited breeding stock is undergoing extensive commercial trials in 1965. A true spherical shape and a polished ebony rind are among new characters in our breeding lines. A small-seeded variant of Charleston Gray was developed from irradiated seed.

### 4. Lettuce

a. Head lettuce. Early generation downy mildew-resistant lines were selected in the field at Brawley, California, and Weslaco, Texas, for horticultural characters; 4 lines were increased at Brawley and 17 at Weslaco for testing in commercial fields. One line, 50588-M, from Brawley is mildew resistant, very uniform, small, but with excellent quality. Uniformity and plant stature make it potentially adaptable to mechanized harvesting.

Nine lines, homozygous for mildew resistance and promising for commercial production in Texas, were increased in Oregon. Most of these lines along with those increased in the summer of 1963 were planted in large plots at 4 locations in the Lower Rio Grande Valley. At least 3 lines, M-2, M-5 and M-6, were mildew resistant and superior in yield and horticultural characters to the commonly used commercial varieties. The policy of growing comparatively large plots for evaluation at several different locations is working well.

Lines derived from irradiated material and from the mutagenic agent, ethyl methane sulphonate; commercial varieties; and Plant Introduction collections were screened for lettuce mosaic resistance. None showed a satisfactory level of resistance. The most promising material for resistance to mosaic are some advanced generation progenies, and backcrosses from an original cross between cultivated lettuce and a line of Lactuca serriola with possible resistance to the virus.

In breeding for big vein resistance, 67 F<sub>5</sub> lines were tested in a commercial field with a history of big vein. About 30 plants were selected from lines showing 24% infection or less, compared with a field level of infection of 81%, and 57% for the most resistant commercial variety, Merit. Progenies from the selected plants will be subject to further big vein testing in 1965.

A natural crossing study in the Imperial Valley with male sterile type 6056 showed a mean crossing rate of 44% and a mean seed set of 52.6 seeds per plant, not adequate for the production of F<sub>1</sub> hybrid seed.

Two new male sterile characters were discovered, and a technique for the induction of temporary male sterility with gibberellins is being explored.

The mode of inheritance was determined and symbols assigned for 5 new genes. Quantitative inheritance studies of height, earliness, and leaf shape in a cross between a head lettuce type and Parris Island Cos are being studied. Also, inheritance of the same characters are being investigated in a cross between two lines of Lactuca serriola.

b. Cos or Romaine Lettuce. Two new lines of cos lettuce were tested in commercial fields in 3 locations in the Imperial Valley and 2 locations in the Coachella Valley. The results indicate these lines are superior to Parris Island Cos for early and mid-season maturity. They are, however, inferior late in the season with the onset of low temperatures.

## 5. Spinach

a. Varietal release. Line S-473, an outstanding item in Texas trials and elsewhere for the past 3 years, has been released to the seed trade as Dixie Savoy. Line S-498 has also proved to be outstanding in Texas and other fall and winter production areas. It is being considered for release in 1965.

b. Hybrid evaluations. In New Jersey a semi-savoy, mildew-, mosaic-resistant hybrid produced excellent yields and a good quality processed product. This hybrid and another promising one will be tested on a commercial scale in 1965. In Maryland, trials of ten experimental hybrids demonstrated that hybrid 59 and two other hybrids were sufficiently long standing to produce heavy yields of excellent quality for late spring harvest. In adaptability trials in Arkansas, four savoy types and two hybrids out-yielded by a significant margin currently used commercial varieties and hybrids. Trials of savoy lines and two semi-savoy hybrids will be repeated in growers fields in 1965.

c. Resistance to white rust. In Texas 13 selections from lines resistant to white rust and 62 hybrids between these selections and mildew- and mosaic-resistant parents were evaluated in the field for resistance to white rust. Four hybrids showed a high level of rust resistance compared with susceptible commercial hybrids.

## 6. Cabbage

a. Quality investigations. Analysis of five families of cabbage from the spring crop averaged 73.0, 69.0, 64.8, 61.2 and 58.5 mg/100 gms. A new source of high ascorbic acid was found in P. I. 275004, a Bulgarian variety called Gergeno Hoko. From this variety, the range was 64-83 mg/100 gms.; and it was fairly uniform for all characters. The low extreme of 64 mg. was within the range of error for sampling.

Several glaze lines grown in Florida, California, and Wisconsin have unusual characteristics of mildness, sweetness, and crispness.

b. Resistance to downy mildew. A variety Chou de Vaugirard d'Hiver was found to have excellent resistance. It was crossed with Round Dutch, and the  $F_1$  progenies show a high degree of resistance, as well as cold tolerance. Screening for other cabbage diseases continue.

c. Red marker gene. In a screenhouse experiment, the outcrossing of the red marker on green (one way) averaged 0.41 percent. In the same experiment, where artificial pollination was not used, the average number of seed produced per plant was 36.3 and 5.6 percent of the siliques produced some seed. Each silique had an average of 2.2 seed. This outcrossing is an added complication to a genetic study under screenhouse conditions.

## B. Diseases

### 1. Muskmelon

a. Downy mildew. An epidemic of downy mildew occurred in the fall crop of muskmelons in the Imperial Valley of California for the first in approximately 30 years.

b. An unusual strain of the tobacco mosaic virus isolated from muskmelon. The muskmelon necrotic fleck virus (MNFV) isolated from plants growing on the Experiment Station, Mesa, Arizona, has been found to be serologically related to the type strain of the tobacco mosaic virus (TMV). It differs from the type strain in host range and disease syndrome in certain hosts susceptible to both strains of TMV. MNFV has been shown to be seed transmitted in 2 muskmelon seed lots.

c. Environment in relation to epidemiology of cucurbit viruses. Preliminary studies at Tucson, Arizona indicated that the cucumber mosaic virus (CMV) strains endemic to Arizona will survive in infected cucurbit plants held at 110°F for 14 days. Isolates of CMV from other regions of the world were inactivated in the same hosts during this period.

e. Virus assays in cucurbits. In cooperative studies with Florida, assays of diseased specimens from cucumbers, muskmelons, and watermelons

indicated that only the watermelon mosaic virus 1 (WMV-1) was present in the central Florida cucurbit producing areas in early 1965. This virus epidemic in central Florida caused an approximate 60 percent loss in the spring cucumber and watermelon crop.

f. Cucurbit serology studies. An antiserum specific for WMV-1 has been produced at Beltsville, Maryland. In cooperation with Arizona, rapid progress is being made at Tucson to produce antiserum specific for WMV-2 and the cucurbit latent virus. These antisera will greatly simplify the identification of these viruses.

g. Cucurbit virus differential hosts. Muskmelon line B 633-3 was found to be resistant to WMV-1 but susceptible to WMV-2. Luffa acutangula was found to be susceptible to WMV-1 but immune to WMV-2. These 2 hosts permit immediate separation, precise identification, and longtime maintenance of these 2 viruses which produce similar symptoms in cultivated cucurbits.

h. Crown blight of muskmelons. Studies at Beltsville, Maryland, indicate that crown blight is a most complex disease. Typical crown blight symptoms have been induced on muskmelon varieties PMRH-5, PMR-6, Campo, Jacumba and Hales Best in the greenhouse following radical changes in weather conditions. A sharp change from cloudy, humid weather to clear, bright days of sunshine with 20-25 percent relative humidity is most conducive to crown blight. Affected plants do not die; however, virus-infected plants do not resume vigorous growth as rapidly as noninfected plants after such an attack of crown blight. Sudden sustained, strong air-movement, particularly when accompanied by a rapid drop in relative humidity in the greenhouse was shown to induce muskmelon crown blight very similar to that observed in the southern California and Arizona production areas. Infection with CMV after fruit set of WMV-1 resistant muskmelon breeding lines was shown to induce typical crown blight and subsequent death of affected plants.

## 2. Lettuce

a. Mosaic. At Salinas, California, the lettuce mosaic virus was shown to be transmissible from diseased plants to healthy ones through gametes of pollen produced on diseased plants.

## 3. Spinach

a. Yellow dwarf virus disease. At Weslaco, Texas, and Beltsville, Maryland, a virus epidemic on spinach in 1963 in the Wintergarden area and the Rio Grande Valley of Texas was identified as the yellow dwarf virus previously reported only from California.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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MUSHROOM BREEDING AND GENETICS,  
DISEASE AND CULTURE

Crops Research Division, ARS

Problem. New and improved materials and methods are needed by the mushroom industry to make it a sound business venture. To assure such a venture, extensive investigations are needed on the microbiology of composting materials, nutritive and environmental physiology, diseases, and the cytogenetics of edible fungi. Such information will permit controlled breeding and improvement of the common mushroom.

USDA AND COOPERATIVE PROGRAM

Applied and basic mushroom studies are conducted at Beltsville on "artificial" or substitute composts, and nutritional and environmental effects on mushroom growth, yield, and quality. Investigations are also underway to devise effective breeding and genetic studies to improve mushroom strains in yield and quality. Two professional man-years were involved in fiscal year 1965.

PROGRAM OF STATE EXPERIMENT STATIONS

Mushroom Culture. Four States are engaged in research concerning the culture of specific fungi which are used as mushrooms for human consumption. Some of this research is directed toward the development of better processing methods; some is directed toward development of improved substrates for the culture of mushrooms; and some is directed toward the isolation of factors controlling size and quality of the mushroom sporophores. The role of ionizing and other radiations on substrate are under study in an effort to find more economic media, and in some cases to use waste or byproducts as substrates. Research is also being directed toward a better understanding of genetic relationships of the principal cultural species and selected exotic species.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Mushrooms

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FLOWER AND ORNAMENTAL PLANT CULTURE, BREEDING  
AND GENETICS, DISEASES AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. Technical problems in the production of flowers and ornamental plants (with a farm value of over a half billion dollars a year), are varied and numerous. There is need for increased research on untouched problems in the culture, propagation, nutrition, physiology, photoperiodicity, genetics, breeding, pathology, and adaptability of these commercially important plants. The industry is demanding answers to these problems. The great expansion of commercial cut flower production out-of-doors is attended by many new problems. Explosive urbanization and expanding interest in civic beautification bring new and more urgent needs for answers to old problems. This group of crops, for which consumer demand is highly elastic, must have expanded research effort consistent with their great expansion of use.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving geneticists, physiologists, plant pathologists, and horticulturists carrying on both basic and applied research on many problems concerned with production of floricultural and other ornamental plants. Breeding and genetics are being done at Beltsville, Maryland; at the National Arboretum, Washington, D. C.; at Tifton, Georgia, in cooperation with the Georgia Coastal Plain Experiment Station; and at Morgantown, West Virginia, in cooperation with the West Virginia Agricultural Experiment Station. Research on diseases is conducted at Beltsville, Maryland, and cooperative with the Georgia Coastal Plain Experiment Station; the Agricultural Experiment Stations of Oregon, Washington, and West Virginia. Experiments for improving cultural methods and growth regulation are carried on at Beltsville, Maryland, and in cooperation with the above Experiment Stations.

Reference collections of living plants and herbarium specimens are maintained at the National Arboretum, Washington, D. C. Promising selections from foreign introductions received through the New Crops Research Branch are propagated at the Arboretum for testing and for distribution to other botanic gardens, arboreta, and experiment stations. Plant specimens are identified and classified.

A contract with the Ministry of Agriculture, India, provides for the study of pyridinonucleotide metabolism in normal and tumor tissue of hollyhock (PL 480).

The Federal scientific effort now devoted to this area totals 24.1 professional man-years divided as follows: Breeding and genetics 11.9 ; diseases 3.8; and variety evaluation and classification 8.4.

#### PROGRAM OF STATE EXPERIMENT STATIONS

There is a growing awareness of need for research on ornamentals at the State Stations. The research serves the need of producers of ornamental plants and provides valuable information and higher quality products for the ever-increasing urban and suburban consumer. There are 95 projects at 27 State Stations concerned with research on culture of ornamentals; but because of the number of plants involved and varying conditions for which research is done, there is very little duplication.

Breeding and variety testing of ornamentals emphasize the development of new plants through varieties better adapted to given areas. There are 53 such projects in 26 States. The breeding of ornamentals at the State Stations is supported by fundamental research in genetics and cytogenetics.

Viruses, fungi, bacteria, and nematodes incite a number of diseases in a variety of ornamentals. Scientists at State Stations are conducting research on viruses of amaryllis, rattle virus of gerbera, and heat treatments in control of orchid viruses. Work with meristem culture in carnations has shown promise in the production of mature virus-free plants. Research is in progress on tuber rot in dahlia, petal blight of azalea, root rot of lily, needle blight of ornamental conifers, and numerous other diseases. Progress in this research will lead to efficient control of these disease problems.

The total research effort in this area at the State Stations is approximately 43.4 professional man-years, of which 28.8 is for culture, 4.0 for breeding and variety evaluation, and 10.6 for disease investigations.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding

1. African violets. Genetic studies of interspecific hybrids reveal that certain phenotypes due to Mendelian genes such as the recessive white or pinks, are not recovered in  $F_2$ , but are subject to modifying genes. Cytological and microscopic analysis of three histogenic layers of colchicine-induced tetraploids confirmed the single cell origin of plantlets from leaf cuttings.

2. Azalea. A single clone of R. occidentale has flowered for two successive years--an unusual occurrence in the East--and has produced good seed set as a hybrid parent. R. bakeri 'Camp's Red' has been internationally registered and is being propagated for distribution. This is a late, strong, red-flowered selection which propagates relatively easily from summer cuttings. The National Arboretum has added 13 species and 80 varieties to its collections.

3. Carnation. Inheritance of 3 variegations has been shown to depend upon the segregation in mitosis and in meiosis of genetic information carried in the plastid. Seedling populations of 2N X 4N parentage have been flowered although their chromosome number has not been determined.

4. Crapemyrtle. Colchicine treatments have resulted in production of 91 selections for cytological analysis as probable polyploids. Thirteen seedling selections have been propagated for field trials in different climatic areas and include an unusual clear red and a fragrant lavender.

5. Daylilies. Statistical studies of stomata size of diploid and tetraploid progenies show that the stomatal means of diploid and the comparable tetraploid populations differ significantly, but genetic variations within each progeny may obscure differences due to tetraploidy. Four additional colchicine-induced tetraploids were obtained in 1964.

6. Hibiscus. Colchicine treatments of H. syriacus have yielded 82 polyploid selections with heavy foliage and flowers of fine substance which remain open for more than a day. A seedling of H. rosa-sinensis has been selected for evaluation outdoors in several climatic areas. Its red, highly ruffled flower remains open several days. Chromosome counts and associations have been determined for an additional 3 clones of H. syriacus, 5 clones of H. rosa-sinensis, and H. brackenridgii var. Kauauiana. The Hibiscus research collection has been increased by 78 accessions during the year.

7. Holly. Ilex (myrtifolia X opaca) 'Tanager' has been internationally registered prior to introduction. This is a female selection combining evergreen foliage of fine texture, red fruit, and compact growth, rendering it suitable for small property landscape use in Hardiness Zone 7 and warmer. Preliminary draft of an "International Registration List of Cultivar Names in Ilex" has resulted from coverage of 141,000 source references.

8. Lilies. (a) Polyploids. A large forcing trial of 20 tetraploid clones was conducted and 5 clones were selected for increase. The amphidiploid species hybrid L. speciosum X L. henryi bloomed and produced larger flowers of greater substance than the diploid hybrid.

(b) Cytology. Chromosomes of the species hybrid L. longiflorum X L. formosanum pair with a very high frequency with an occasional reversion bridge and fragment. The chromosomes of the diploid hybrid L. speciosum X L. henryi form very few bivalents and meiosis is very irregular.

(c) Endosperm breakdown in L. speciosum X L. auratum hybrid. The endosperm develops to unusually large size in some seeds and most embryos are killed before reaching maturity. Isolated large cells containing from 3 to 8 nuclei were found in mature embryos. Such cells were surrounded by soft, dead endosperm.

(d) Backcross populations derived from pollen of species hybrid applied to one parent. Pollen from the hybrid L. speciosum X L. henryi produced seedlings on L. speciosum album and rubrum.

9. Magnolia. Selections from hybrid populations of M. stellata X M. liliflora and M. kobus X M. 'Reflorescens' are ready for vegetative propagation and cooperative testing. M. liliflora has been effectively mated with M. sprengeri 'Diva' in effort to produce better midseason-flowering magnolias in the crimson to rose-purple color range.

10. Pieris. Herbarium specimens and color photographs have been prepared from 37 accessions in Pieris. Further hybridization has been delayed pending better flower production by maturing parental selections.

11. Poinsettia. After extensive trial, seedling No. 61-156-1 has been introduced under the name 'Spring Pink'. The pink bract color was transferred from wild plant material introduced from Mexico.

12. Pyracantha. A seedling population of 16,250 plants has been obtained from 96 out of 108 crosses made in 1964. Research files have been enriched by the addition of 174 flowering and fruiting specimens and many photographs in course of field evaluation of Pyracantha cultivars and selections. Work continues on preparation of a registration listing of cultivar names.

13. Red Bud. In process of evaluation are 73 selections from an 860 F<sub>2</sub> generation of Cercis canadensis X C. chinensis and 422 hybrid seedlings of C. chinensis, C. reniformis, C. canadensis, and C. siliquastrum.

14. Rhododendron. F<sub>2</sub> hybrids and backcrosses of R. smirnowi are being raised in the expectancy that leaf indumentum of this species will be recovered in sufficient amounts to discourage attack by rhododendron lace bug. Further selections are under test from crosses of R. carolinianum, racemosum, and vilmorinianum. Thirteen species have been added to the collections.

15. Roses. Response to temperature in terms of flower initiation, petal differentiation, seed set, and seed germination were determined for a number of species and are described in publications listed.

16. Stock. Results were published of an experiment confirming the sensitivity of seed set to small changes in the level of nutrition which became evident at or soon after fertilization.

16. Variegations. The inheritance of the chlorophyll variegations through cytoplasmic units of heredity has been determined in both vegetative and sexual reproduction in tobacco, poinsettia, carnation, soybean, and Rose-of-Sharon.

18. Viburnum. Current hybrid selections in process of evaluation comprise 9 Viburnum carlesii types, 11 V. plicatum and tomentosum types, and 26 types involving V. hupehense, dilatatum, erosum, and wrightii. Chromosome counts have been obtained for an additional 5 species and 6 cultivars. An addition of 19 accessions brings the research collection to 939 plants comprising 195 species and cultivars, exclusive of breeding stocks.

19. Herbarium Collections. Herbarium reference collections have been augmented by acquisition of the 70,000 species, Isaac Martindale Herbarium of the Philadelphia College of Pharmacy and Science; of 3,000 specimens from the 1964 F.A.O. coffee mission expedition to Ethiopia and of materials resulting from research projects in breeding and classification. A survey of the willows and poplars of Nevada has been completed.

## B. Diseases

1. Fusicladium pyracanthae on Lalandi Pyracantha was controlled by dodine sprays. Treated plants retained more foliage through the winter giving better plants for bloom and berry production.

## C. Culture

1. Pigments - Anthocyanins. Approximately 100 mg of the anthocyanin in Better Times rose petals were isolated, identified, and crystallized. This pigment will be used in studies designed to give information on the natural state of anthocyanins in plants.

A preparative thin-layer chromatographic procedure was devised which greatly reduced the time necessary to purify anthocyanin pigments.

2. Controlled atmosphere storage of cut flowers. Experiments aimed at prolonging the display life of cut flowers by storage in reduced oxygen as well as total nitrogen atmospheres were carried out with daffodils, lilies, roses, and gladiolus. Only daffodils responded favorably and were comparable to freshly cut flowers.

3. The dependence of flowering in several long-day plants on the spectral composition of light extending the photoperiod. Brief light breaks in the middle of each night failed to cause flower induction. Extended breaks, and 8-hr extensions of the photoperiod were effective, particularly those with light from BCJ, Ruby Red, and incandescent lamps. Fluorescent lamps were ineffective. For all lamp types and plant species, 8-hr extensions prior to each daylight period were more effective than those given at the end of each day. Four-hour light breaks were most effective when given in the middle of each night. The flowering caused by 4-hr breaks with BCJ light from 8 PM to 12 PM was suppressed when the BCJ light was preceded by 4 hr of fluorescent light. When light from BCJ or

fluorescent lamps was interpolated for 2 hr at various times during 8-hr extensions with light from the other type of lamp, BCJ light stimulated flowering the most; and fluorescent light inhibited it the most when interpolated at the end of the daylight period.

4. Action of growth retardants on cultivars of rhododendron. The standard growth retardant-photoperiod was used to evaluate the usefulness of 24 rhododendron hybrids and 4 seedling populations. The cultivars varied greatly in their response to photoperiod, growth retardant, and forcing performance. Most cultivars initiated flower buds in response to the growth retardants and long days. America, Chionoides, Madame Masson, Nova Zembla, Rosa Mundi were useful cultivars for the promotion of early flowering. R. catawbiense f. album (Glass) Rehder formed abnormal flower buds. During forcing, cultivars such as Alice, Crimson Glory, and Pink Pearl dropped their foliage. The flower buds on the cultivars Caractacus and Jean Marie de Montague were bypassed with vegetative growth, and Dr. Rutgers and Edward S. Rand did not develop their flower buds. Because seedlings varied greatly in response to light and growth retardants, only 20% formed flowers; the remaining plants either remained in vegetative growth or were suppressed completely from growing.

5. Regulating flowering of Bromeliads. Various ornamental Bromeliads were grown on a photoperiod regulated to keep them vegetative. Plants were selected for treatment when they were large enough to flower and with well-established root systems. They initiated and developed flowers when treated with solutions of Beta-hydroxyethylhydrazine (Omaflora). The flowering of 11 species (Billbergias, Vriesias, Ananas) was induced with 0.1 and 0.2% Omaflora. Higher dosages (0.5%) damaged the foliage and the growing point; many vegetative basal offshoots developed. Omaflora had no effect on 4 species in the juvenile grass-leaf stage and killed plants of Wittrockia superba Lindm. at all dosages tested.

6. Growth retardant B-Nine for genetically tall-growing greenhouse hydrangea. The tall-growing, late-flowering greenhouse hydrangea cultivar Rose Supreme produced short compact plants when sprayed with appropriate concentrations of N-dimethylaminosuccinamic acid (B-Nine) in midsummer to control vegetative growth or 2 weeks after dormancy-breaking cool storage in the winter to prevent excessive flower stem elongation. Retardant-treated plants can be used as stock plants for cutting production.

7. Year-round flowering of azaleas made possible with growth retardants and environmental control. Commercially important greenhouse azalea cultivars were flowered at will throughout the year provided they were maintained in active vegetative growth by means of additional light and favorable growing temperatures in the winter and greenhouse cooling in the summer, then sprayed with the growth retardants 2-chlorotrimethylammonium chloride (Cycocel) and B-Nine to check growth and initiate

flower bud development. Cool storage at 50°F or lower was necessary for satisfactory flowering. Temperatures of 50° hastened flowering over storage at 35°, and durations of 6 weeks were preferable to shorter periods.

8. Iris. Flowering affected by air temperatures during bulb production and forcing. Extent of accumulation of degree-days based upon daily departures above 65°F for the period June 20 until bulb harvest in Washington State was positively correlated with earliness and ease of forcing Wedgewood iris. Delayed maturity characteristic of cool summers, was offset to some extent by artificial heat curing. After dormancy-breaking cool storage excessive air temperatures in the greenhouse seriously reduced forcing performance. Exposure of iris bulbs to atmospheres containing low concentrations of ethylene accelerated flowering and reduced excessive vegetative growth. (In cooperation with Western Washington Experiment Station.)

9. Ranunculus bulbs for production of potted plants. California-grown Ranunculus bulbs were vernalized for 3 weeks at 50°F and forced in the greenhouse during the winter and spring. The growth retardant B-Nine as a foliar spray or soil drench reduced normal excessive height and produced compact flowering potted plants.

10. Easter lilies. Storage conditions for forcing tetraploid Easter lilies. High temperatures, 70° to 80°F, maintained dormancy of tetraploid Easter lily bulbs more effectively than did low temperatures and without the damaging side effects (reduced number of leaves and flowers) of the latter. Exposure of the heat-stored bulbs to temperatures of 50° or lower for a minimum of 6 weeks was necessary for prompt forcing and made possible a continuous season of bloom throughout the winter and spring.

11. Forcing accelerated by soil treatments with systemic insecticides during bulb production. Phorate (Thimet) applied at rates of 4 to 20 lbs. per acre in Oregon for control of aphids stimulated emergence and final height of Ace and Croft Easter lily plants forced in the greenhouse. Di-Syston had similar but less pronounced effects. (Cooperative with the Entomology Research Division.)

12. Bulb production. At Tifton, Ga., several nematocides applied in a single injection application 10-12 inches deep before planting resulted in an increase of lily bulb size. Fertilization with nitrogen and potassium did not increase bulb yield, but uramite increased flower and stem number; yield was not affected. The herbicides, diuron, dimethyl ester of tetrachloroterphthalic acid, dichlorobenil, and diphenamid, controlled weeds in the order listed without affecting bulb yield. (Cooperative with the Georgia Agricultural Experiment Station.)

13. Forcing lilies. Lily bulbs potted and plunged outside bloomed in 75-100 days depending upon the time forcing began. Cooling bulbs 2-4 weeks before potting and plunging produced earlier blooming when forcing started early. Cooling of plants after the period outside did not affect time of bloom. Storage of bulbs at 80°F before cooling delayed blooming and resulted in a better-shaped plant.

14. Azaleas. Azaleas grown in the greenhouse at 70°F, treated with N-dimethylaminosuccinamic acid or 2-chlorotrimethyl ammonium chloride in mid-December, and cooled February 17 - April 6, bloomed in mid-May. Those treated in mid-January and cooled March 9 - May 4 bloomed in early to mid-June. Untreated plants produced very few blooms.

15. Camellias. Gibberellic acid applied to Ville de Nantes camellia flower buds on three dates gave earlier, larger, and longer lasting blooms. (Cooperative with the Georgia Agricultural Experiment Station.)

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SHADE, ORNAMENTAL AND WINDBREAK TREE  
CULTURE, BREEDING AND DISEASES

Crops Research Division, ARS

Problem. Homes, farmsteads, and municipalities have huge sums invested in shade trees and windbreaks, and more and better plantings are urgently needed in countless localities. Each year thousands of valuable shade trees are killed by diseases. Removal of dead trees is expensive in cities, and decades are required to replace mature trees killed by disease. Costs of control measures now available are estimated at several million dollars per year and are increasing; there is need to develop more efficient controls, including disease-resistant types of trees. There are numerous leaf spot diseases of trees, and the causal organisms of many are not as yet known. Numerous diseases of still unknown cause continue to kill sweet gum, scarlet oaks, pin oaks, and white ash in home and ranch plantings. The climate of the Great Plains with its low rainfall, high winds, hot summers, and cold winters makes it difficult to establish woody plantings; and research is needed to improve methods of establishing woody plants under such conditions. Hardiness, species adaptation, planting distances and arrangements, responses of plantings under different environments, and the nature of conservation of moisture and soil by windbreaks are problems that require additional research. Studies are needed to measure crop responses to windbreaks of various types under different conditions in comparison with other means of soil and crop protection from wind.

USDA AND COOPERATIVE PROGRAM

In Department research, special attention is being given at Beltsville, Md., and Delaware, Ohio, to the search for chemical cures for trees affected with Dutch elm disease and at Beltsville, Md., and Tifton, Ga., to chemical controls for mimosa wilt. Limited, but important research on diseases of live oak, especially live oak canker, and blight of sweet gum is done at Beltsville. At Beltsville, additional basic research is conducted to determine the nature of many other tree diseases of unknown cause. At Mandan, N.D., research is concerned with effects of windbreaks on crop yields, spread of snowfall, and soil erosion. The culture and handling of shade trees and windbreak studies on culture and effect on crop yields are carried on at Cheyenne, Wyo. Research on shade tree diseases is conducted at Delaware, Ohio, in cooperation with the Ohio Agricultural Experiment Station.

Research is being conducted under a contract with the College of Agriculture, University of the Philippines, on the host range and transmission of the cadang-cadang disease of coconut palm (PL 480).

The Federal scientific effort now devoted to this area totals 8.2 professional man-years divided as follows: Diseases 4.7, breeding .5 , and culture 3.0.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Windbreak research is being carried on by most of the Experiment Stations in the Great Plains States and several other stations. The program includes all major types of windbreak research. Studies in progress include effects of field windbreaks on movement of wind, soil and water, and on crop yield; genetic improvement of windbreak materials; soil and site requirements; and design, establishment, and management problems, including protection from diseases and insects. Five of the current projects were initiated in 1964 under the McIntire-Stennis Cooperative Forestry Research Program.

Windbreak research program, needs, and coordination are being studied by the USDA Windbreak Research Committee and the Forestry Committee of the Great Plains Agricultural Research Council. The two groups are working together to project future needs for windbreak research in various categories under the combined programs of Federal agencies and State Experiment Stations.

Research on woody ornamentals and shade trees is in progress in a number of States. It embraces studies on propagation and stock handling, nutrition, and winter injury and breeding, as well as development and maintenance of arboreta and herbaria for native and introduced species.

The total research effort at the State Stations reported here is approximately 33.0 professional man-years, of which 3.5 is for culture, 5.2 for breeding, and 24.3 for diseases.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding

1. Elm. In cooperation with the Ohio Agricultural Experiment Station, selections of Ulmus americana and elm selections and hybrids from the Netherlands that have shown resistance to Dutch elm disease were inoculated with a spore suspension from 8 isolates of Ceratocystis ulmi. Plants showing disease symptoms in more than 15% of the crown were eliminated. Resistant survivors were propagated by means of softwood sprouts from root cuttings. This method of propagation was only moderately successful.

2. Woody ornamentals. At Cheyenne, Wyo., populations of seedling Amur maples are being produced from seed of trees selected for superior foliar color, form, and fruiting habit. One seed parent, selected for outstanding fruit color plus freedom from chlorosis, is being propagated vegetatively. Seedlings of several other shrub and tree species are being produced for future evaluation of hardiness and horticultural desirability. Results of a preliminary trial indicate that etiolation or etiolation plus girdling of stock plants enhances rooting of cuttings of dogwood and elder. Girdling alone inhibited rooting of both species.

## B. Diseases

1. Elm. Tests were made of the effectiveness of the amino- and sodium salts of trichlorophenyl acetic acid as a suppressant of Dutch elm disease in American elm. Soil treatments were ineffective at concentrations of the chemical below phytotoxic level. Residual toxicity of the chemicals in the soil after two growing seasons was noted on elm, sweet gum, and gardenia. The salts were also applied to the trunks of 15-to 20-foot American elms. No reduction of disease over untreated checks was obtained. However, when a penetrant, dimethyl sulfoxide, was combined with either the amino- or sodium salt of trichlorophenyl acid, only 25% of tops developed symptoms of Dutch elm disease when the tops of checks had 63%. This degree of control is not adequate for practical use. It is significant, however, that DMSO acted as a carrier penetrant.

One proprietary mixture (X-DEA), widely advertised as a control for Dutch elm disease, failed to control the disease in our tests and was phytotoxic to American elm.

Water extracts from stems and leaves of 1- to 4-month-old elm seedlings greatly inhibited germination of C. ulmi spores, while extracts from their roots and from the stems and leaves of 6- to 8-year-old elms stimulated spore germination. Both the anion and neutral fractions of the inhibitory leaf extracts were found to inhibit spore germination while the cation fraction stimulated germination. (Cooperative with the Ohio Agricultural Experiment Station.)

2. Oak. Seedling live oaks did not develop cankers following inoculation with Endothia parasitica. Greenhouse-grown cork oak seedlings developed cankers following inoculation with Endothia parasitica. Spores of the fungus were reisolated from them.

3. Saguaro. In cooperation with the University of Arizona and the National Park Service, study was continued of the saguaro rot at the Saguaro National Monument. Between February 1964 and February 1965, 12 of 838 (1.4%) saguaros died from bacterial necrosis in 60 acres of plots at the Saguaro National Monument. This is the second consecutive year of less than average mortality. Reasons for the decrease are not known. Continued comparative studies of several species of Erwinia utilizing various media and biochemical tests indicate that E. carnegieana and E. aroideae are closely related, if not the same. While homologous antisera reacted with whole cell antigens of these species, no cross reactions occurred between whole cell E. aroideae antigens and serum for the E. carnegieana whole cell antigens. Sixteen of 44 E. carnegieana whole cell antigens reacted with E. aroideae serum. Continued efforts to find a phage for E. carnegieana have not been successful.

A virus-like symptom has been noted in four species of Opuntia cacti native in Arizona. Intracellular crystals are associated with the symptoms and virus particles have been isolated. These cause local lesions in leaves of Chenopodium amaranticolor and C. quinoa. Saguaro seedlings were found to be susceptible to Verticillium albo-atrum.

4. Coconut Palm. Coconut palm research in cooperation with the University of the Philippines on cadang-cadang of coconut palm was continued on PL 480 funds. No evidence was obtained of transmission of a virus disease from weeds to coconuts using three inoculation techniques and four carrier solutions. Completely satisfactory evidence was not obtained that cadang-cadang is caused by a virus but there was some preliminary indication that the disease may be virus caused.

### C. Culture

1. Materials, production and management of farmstead windbreaks. At Mandan, N. D., superior clones of Ulmus pumila, U. japonica, Celtis occidentalis, and Caryopteris mongolica were distributed for wider testing. Certain tree and shrub races from Oklahoma and Kansas suffered greater injury from freezing than races from Nebraska and North Dakota. Grade 1 trees of a 4-grade seedling selection in 1941 are now 8 feet taller and 2.1 inches greater in diameter than grade 4.

2. Crop plant response to field windbreaks (shelterbelts). At Mandan, N. D., single- and multiple-row field windbreaks spaced 2 to 4 feet in the row formed snowdrifts up to several feet within a 30-foot area on the lee side. Deciduous tree species spaced 12 feet apart formed shallower drifts spread over an area 100 or more feet wide. Winter soil blowing was reduced and crops could be planted earlier on the lee side of wider spaced belts. Two rows of corn, sunflowers, or sorghum planted at intervals of about 100 feet were highly effective in holding snow and reducing snow blowing. Wheat yields on the lee side of a noncompetitive barrier in an area equivalent to 12 barrier heights averaged 27.2 bushels per acre compared with 18.9 bushels in a like area on the windward side.

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## REPLACEMENT CROP INTRODUCTION AND EVALUATION

Crops Research Division, ARS

Problem: American agriculture is based on the expanding culture of crops, most of which have originated outside our continental limits. The improvement of existing crop varieties, the selection of new lines with natural resistance to insects and diseases, and the development of any number of important characteristics are dependent on a continuous flow of introduced germ plasm. Inherent in this is the preliminary evaluation and cataloging of plant introductions for traits which will be of use to plant breeders and the agronomic development of potential crops as a result of joint botanical-utilization screening research on new crops. These demands require the search for and introduction of 8 to 10 thousand plant collections and samples for analysis yearly.

### USDA AND COOPERATIVE PROGRAM

The nature of this program is to conduct investigations concerned with the introduction, evaluation, and maintenance of plant germ plasm for the development of a strong yet diversified agriculture for the United States. Both basic and applied research is undertaken in the areas of: assessment of the world's plant resources; search for diverse germ plasm in the world centers of crop origin, and exchange of improved types; evaluation of introductions through a national cooperative program as breeding stocks, sources of natural resistance to crop pests, potential new crops, and other uses brought about by shifts in agriculture; and the preservation of important segments of germ plasm either as seed or as vegetative stocks. Leadership for this program is at Beltsville, Maryland.

Four national introduction stations are responsible for evaluation, maintenance, and/or quarantine of new introductions which require special handling: Chico, California; Miami, Florida; Savannah, Georgia; and Glenn Dale, Maryland. The responsibility for preservation of seed stocks of national interest lies with the National Seed Storage Laboratory, Fort Collins, Colorado. Cooperative new crops studies to determine significant agronomic characteristics of plants having valuable end-products are conducted cooperatively with Experiment Stations of Alabama, Montana, Nebraska, North Carolina, South Carolina, and Texas. Four regional and one inter-regional introduction stations deal with the evaluation of crop breeding stocks essential to programs in State Experiment Stations.

Fifteen PL 480 projects are active, all dealing with research on the collection and evaluation of native plants of potential use in the agriculture of the United States. The countries and number of projects are as follows: Colombia - 1, India - 6, Israel - 2, Korea - 1, Pakistan - 1, Spain - 1, Turkey - 1, Uruguay - 1, Yugoslavia - 1.

The Federal scientific effort devoted to research in New Crops totals 41.5 man-years. Of this number, 4.0 are devoted to international plant exchange, 4.7 to botanical investigations, 5.7 to special plant procurement and related botanical activities. Research on new crop evaluation includes 7.7 man-years for horticultural research, 3.8 for agronomic studies, 6.1 devoted to evaluation of potential new crops, 6.0 to pathology, and 3.5 to maintenance of germ plasm.

#### PROGRAM OF STATE EXPERIMENT STATIONS

While responsibility for collecting and introducing plant material into this country rests predominantly with the Department, the State Stations cooperate actively in the preservation, multiplication, and preliminary evaluation of such materials and in domestic and other explorations for the introduction of new materials. An elaborate system supported in part by the States and in part by the Department has been organized for the purpose of placing introduced materials in the hands of interested plant researchers throughout the country. This system consists of a series of 5 plant introduction stations located respectively in Geneva, New York; Experiment, Georgia; Ames, Iowa; Pullman, Washington; and Sturgeon Bay, Wisconsin. Research of the State stations is organized and coordinated through 5 regional projects: NC-7, New Plants - for Industrial and Agricultural Utilization; NE-9, Discovery and Preservation of Valuable Plant Germ Plasm; S-9, The Introduction, Multiplication, and Evaluation of New Plants for Industrial and Agricultural Use and the Preservation of Valuable Germ Plasm; W-6, The Introduction, Multiplication, Preservation, and Determination of the Value of New Plants for Industrial and Other Purposes; and IR-1, Introduction, Preservation, Classification, Distribution, and Preliminary Evaluation of Wild and Cultivated Species of Solanum. All 50 States and Puerto Rico cooperate in this research. Cooperation between the State Stations and the Department in this program is outstanding and of great mutual benefit.

The total research effort on replacement crop introduction and evaluation at the State Stations is approximately 50.1 professional man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Plant Introduction

1. Breeding Stock Introduction. The plant exchange program in 1964 resulted in 9,188 introductions from and 1,654 shipments to 119 different countries. Ornamentals (1,034) were among the largest groups.

a. Foreign exploration. In connection with investigations of cultivated plants and correlated studies to locate potential sources of disease and insect resistance, an initial study on gene centers for cultivated beans is

being used as a basis for plant exploration presently underway in Latin-American countries. Similar information will be used for collecting Phaseolus species of Old World origin. Another study is underway on Cucumis and will be utilized in the search for natural resistance to diseases affecting this plant group. Literature review and bibliographic files have been started pertaining to sources of other economically important diseases such as the corn stunt viruses.

b. Domestic exploration. The major accomplishment was placing on inventory 475 collections from the Great Plains States of woody ornamentals assembled in 1963 and 1964 under supervision of the University of Nebraska (NC-7). Emphasis was placed on hardiness and growth types suitable for highway landscaping and erosion control. Additional germ plasm obtained for other regional domestic exploration projects included 22 Vaccinium (NE-9), 41 Prunus, Pyrus, and Malus (S-9), and 20 Ceanothus (W-6).

c. Support for AID missions. The special plant project provided AID missions with a total of 1,050 lots of seeds or plants. While the total number of countries served remained about the same as in previous years (40), the amount of plant material was somewhat less and of a different nature. The agricultural programs in many missions have developed to the stage where breeding material and newer varieties are requested rather than large quantities for screening purposes. Specially devised forms for reporting plant performance were distributed to the missions. Lists of plant materials supplied by the Branch to missions from 1955-63 were prepared and distributed in circular airgram form. The missions were requested to complete the forms for as many items as could be identified and for any other plant materials, native or received from other sources. Some of the reports that have been returned are of great value to the Branch in recommending further materials for trial by the reporting mission and other missions having similar conditions.

d. Maintenance of germ plasm. Approximately 6,000 items were added in 1964 to the NSSL long-term storage, bringing the total to 34,750. Considerable progress was made in getting soybeans and rice world collections. Practically all obsolete varieties of various crop seeds still available were located. Periodic germination tests revealed no evidence of deterioration of any crop seed with the exception of lettuce. These develop red cotyledons, a physiologic change being studied further.

After four years of storage, seeds of lettuce, safflower, sesame, crimson clover, and sorghum retained their viability very well with 10% moisture and 50° F. At temperatures above 50° F., crimson clover and sorghum seeds retained their viability better than the other three crops.

The third part of the survey of fruit and nut clones was completed with the publishing of ARS 34-37-3, A Survey of Pears, Nuts, and Other Fruit Clones in the U.S. The National Coordinating Committee (New Crops) has appointed a new subcommittee to determine utilization of these surveys in proposals for national repositories.

One issue of the Printed Inventory (No. 163) appeared in 1964 covering introductions received in 1955. Four additional manuscripts (Years 1956-59) are at the printers or in editorial review.

## B. New Crop Evaluation

Evaluation of Breeding Stocks. Research emphasis is directed toward evaluation of germ plasm as sources of natural resistance to plant pests; determining characters which will enhance adaptation and crop versatility; and development of new varieties of agronomic, horticultural, and chemurgic crops at Federal introduction stations and through regional cooperative programs.

### 1. Horticultural Crops.

a. Fruits and nuts. Screening programs for adapted fruit varieties and disease resistance are particularly active. The current trend is to supply more elite germ plasm to cooperators. Requests are for materials as free as possible from virus diseases and with as much background information as possible. During 1964, 21 virus-free stone fruit introductions were released by the Glenn Dale Station. Research was initiated at Glenn Dale during the year on indexing procedures for apples and pears.

Information about fruit and nut introductions is supplied in the research report series, Evaluation of Foreign Fruits and Nuts. Report No. 13 (published as CR-42-64), completed at Chico during the year, contains evaluation data on 127 introduced plum varieties.

One of the most frequently requested characteristics is early fruit maturity for both the northern and southern fruit-growing areas. Many apple introductions were supplied to cooperators in south-central Georgia. Fruit growing is expanding in this area as a replacement for row crops.

Two early ripening sweet cherry introductions, 'Moreau' and 'Early Burlat', are outstanding in California. Growers received \$24 per lug for these varieties during 1964 while older varieties were bringing only \$6 to \$8.

An apple introduction, 'Tydeman's Early Worcester', that ripens in early fall with a good red color is highly regarded in Oregon.

During recent years, the pistachio nut has received considerable attention as a new nut crop for California. Many demands have been made on the Chico Station for information and propagation material. Commercial orchards now total about 500 acres, varying in age from recently budded to full bearing. Seeds of rootstock species to plant an additional 400 acres have been distributed.

Several years of effort have shown little improvement in texture, flavor, or size of fruit of jujube varieties. There are indications that it may be possible to select from seedling populations for spinelessness of the branches and blunt-tipped seeds.

b. Vegetables. Disease, insect, and nematode resistance continue to be the most sought after characters in vegetable introductions. In some kinds of vegetables, the present germ plasm collection appears to be adequate; in others, satisfactory levels of resistance to important diseases have not been discovered. The pathogens causing vegetable diseases often develop new races making resistance an unstable character. New sources of resistance can be supplied only by continuing the present program of plant introduction. A series of reports initiated during the year by phytopathologists located at the regional stations summarizes sources of resistance in plant introductions to diseases, insects, and nematodes. Four of the reports pertain to vegetable crops.

Sources of cold tolerance, male sterility, plant habit, and quality of edible product are also being used in breeding programs.

During the year, 100 potato introductions were indexed for virus diseases. Of these, 26 introductions were released as virus negative and 74 positive. Four new potato varieties were released for commercial production in the United States in 1964 by plant breeders. The numbers of foreign introductions entering into the pedigrees of these varieties are 3, 2, 3, and 7, respectively.

Five new introductions of sweetpotato from New Zealand were distributed to 10 ~~State~~ and Federal Stations for testing and possible use in plant breeding programs.

Screening tests at the S-9 Station revealed 5 sources of resistance to bacterial spot of pepper.

An introduction of Lycopersicon pimpinellifolium, P.I. 127805, was used to determine the genetics of resistance to bacterial wilt in tomato.

New sources of resistance to anthracnose in cucumber were reported by NC-7. This region also evaluated 250 tomato introductions for soluble solids and sugar/acid ratio.

The S-9 Region reported finding 8 sources of resistance to cowpea chlorotic mottle virus.

Vegetable varieties released during the year with germ plasm from plant introductions are: 'Gem', sweetpotato - North Carolina; 'Valmaine', lettuce - USDA and Texas; 'Eversweet', cucumber - Robeson Quality Seeds, Inc., Hall, N. Y.; 'Butter King' lettuce - Canada; 'Male-sterile 2', cantaloupe - USDA; 'Large German Cherry', tomato - Oregon; 'Campo', cantaloupe - Arizona and USDA; 'Jacumba', cantaloup - California and USDA; and 'Floricream', cowpea - Florida.

c. Ornamentals. At Glenn Dale, preliminary results show that introduced Camellia species with fragrant flowers will cross with varieties of the Japanese Camellia. At Chico, selections of Acer truncatum are proving valuable for fall-foliage color. At Miami, preliminary evaluation of seedlings from woody plant introductions has shown that this will be a rewarding type of research.

The Crops Research Division, Beltsville, has released 'Spring Pink', a poinsettia variety bred from P.I. 247812. 'Spring Pink' has bracts of a very uniform light-pink color. It flowers after the Christmas season and throughout the spring.

Introductions of chrysanthemum from Japan have been released as cold-hardy varieties for the Northern States and have been used in breeding additional varieties.

The selection of Ligustrum vulgare, from P.I. 107630, which has proved outstanding for cold hardiness in the North Central States, has been named 'Cheyenne' and released jointly by the north-central region and the Crops Research Division.

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SEED CROP CULTURE, DISEASES, PHYSIOLOGY,  
NUTRITION, HARVESTING, AND VARIETY EVALUATION

Crops Research Division, ARS

Problem. Normal vegetable seed supply is adequate, but geographic concentration of the seed industry is potentially hazardous. Mechanization of the vegetable industry requires increased emergence and uniformity of seedling development, but improvements in processing quality of vegetables often decrease seed quality. There is insufficient basic knowledge of physiology of seed development and germination as these influence the crop-producing potential of seeds and potential industry mechanization.

USDA AND COOPERATIVE PROGRAM

Vegetable Crops. Basic research on physiology and biochemistry of vegetable seed germination and seedling vigor is carried out at Beltsville, Maryland. At Logan, Utah, in cooperation with the State Agricultural Experiment Station, studies involve seed quality as controlled by environmental conditions, including cultural and harvesting practices. Beltsville and Logan programs are closely coordinated. Federal scientific effort totals 2.0 professional man-years, of which 2.0 are on germination physiology and biochemistry and 1.0 on the physiology of seed development.

In India, under P.L. 480 projects, research includes physiology of development of ovules and other reproductive organs and early production of ascorbic acid and ascorbic acid oxidase and the metabolism of bound forms of nicotinic acid (niacinogen) in germination. In Israel, submicroscopic structural changes in mitochondria and other cellular structures are studied in close cooperation with Beltsville scientists.

PROGRAM OF THE STATE EXPERIMENT STATIONS

Scientists at the State Experiment Stations are engaged in basic and applied research in physiology, pathology, agronomy and engineering pertaining to seeds. In several States, the research is conducted cooperatively with the Department. This research is continuing to provide useful fundamental information for the improvement of seed crop culture, harvesting, and storage. Two regional projects have been organized by the States to coordinate research on seed problems. In the northeastern region under NEM-22, chemical, physical, physiological, morphological, pathological, and other means of determining varietal purity of seeds are being sought. In the Western region under WM-35, much attention is being given to developing and improving techniques for rapid estimation of viability of seed, factors during growth affecting viability, harvest and storage factors relating to poor germination, and improved laboratory methods of determining the viability of and purity of range grass seed. Other studies concern management of seed production fields for forage seed, control of

insects, effect of growing conditions on seed quality, harvesting equipment, and drying practices. Seed storage research concerns factors associated with seed deterioration, the sequence of physiological changes, storage factors affecting these changes, seedborne microflora, and the use of seed coatings. Testing procedures for germination, vigor, and stand-producing potential are receiving much attention. Some work is being done on blending seed for uniformity. Various means of breaking seed dormancy including radio-frequency electric fields are being explored. In addition to studies on seed production and seed technology, most of the States are involved to some degree in producing breeder, foundation and certified seed of newly developed crop varieties.

Disease problems of the major seed crops of vegetables, ornamentals, forages, and field crops are being studied. Seed-borne diseases are known to limit production. In addition, there is an increased demand upon seeds to provide a plant that meets exact requirements for culture, harvesting, processing, and product quality. The need for knowledge on disease problems has increased. Some of the research in progress is designed to provide new knowledge on specific causal agents of disease. In other projects, scientists are concerned with isolating the components of resistance to disease, so that these may be used by plant improvement specialists and others to provide resistant plants of commercial value. A number of projects are designed to provide the critical histological and histochemical evidence that is essential to the study of certain seed crop diseases. The role of fungi and bacteria in the deterioration of seeds is being emphasized in some projects.

The total research effort in this area of research is 19.1 professional man-years - of which 1.4 is for culture, 0.5 for diseases, 3.3 for physiology, 1.0 for harvesting, and 12.9 for variety evaluation.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

### Physiology

Temperature relations in bean germination. In Beltsville, Maryland, research, the earliest stage in imbibition of lima bean seeds and excised embryonic axes is temperature sensitive. Imbibition at 60°F. or lower reduces subsequent growth at 76°; imbibition at 76° protects against subsequent chilling injury. Low vigor (bleached) seeds are more sensitive to injury than high vigor green seeds. Seed responses can be variable because the seed coat may restrict water uptake permitting the seed to avoid chilling injury. This protective mechanism is most effective at low temperature under relatively dry conditions. Thus the total temperature sensitivity is complex and can result in extremely variable seed germination. Snap bean varieties released prior to 1955 are not susceptible to chilling injury, but many newer varieties can be extremely sensitive, even to 68°F, a normal germination temperature.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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## NEMATODE IDENTIFICATION, PHYSIOLOGY, AND CONTROL

Crops Research Division, ARS

Problem. Plant-parasitic nematodes attack most crops in the United States, causing a loss estimated at more than 370 million dollars a year for only 18 of the crops grown in the United States. Most plant-parasitic nematodes infect roots and other underground parts of plants; but some very important species attack bulbs, stems, leaves, and flowers. Damage initiated by nematodes is often extended by bacteria, fungi, and viruses. Control methods include use of nematocides, crop rotations, cultural practices, resistant varieties, and biological agents. Damage can be greatly reduced by use of varieties resistant to nematodes, but only a relatively few resistant varieties have been developed. Development of resistant varieties is a time-consuming task and does not completely protect the crop because multiple nematode resistance is difficult to attain and is lacking in all varieties thus far developed. Crop rotations have been devised to reduce some of our more important nematode problems, but rotations rarely fit modern management practices or are uneconomical. While naturally occurring biological agents undoubtedly have a great influence on nematode populations, manipulation and use of these principles for economic control of nematodes is not yet practical. Great advances have been made in chemical control, but use of nematocides on many crops is not economically feasible. Additional research is required to improve all methods of nematode control for annual crop plants and to develop methods of controlling nematodes on perennial crops in orchards, groves, vineyards, and nurseries. To aid in this research, expanded basic studies of taxonomy, pathology, physiology, nature of resistance, genetics, and the ecology of nematodes are needed.

### USDA AND COOPERATIVE PROGRAM

The Department has a long-term, continuing program of basic and applied research on various phases of nematology which contributes information of value to nematode control. In the past few years, as State nematology programs have developed, there has been increased emphasis on basic research by the Department. Research of nematodes affecting citrus is located at Tempe, Arizona; Orlando, Florida; and Weslaco, Texas; on vegetable crops at Tifton, Georgia; Charleston, South Carolina; Salinas, California; and Weslaco, Texas; and on ornamentals at Tifton, Georgia. The work in all States except Florida and South Carolina is in cooperation with respective State Agricultural Experiment Stations. In addition, there is a P.L. 480 project at La Molina, Peru, for research on the golden nematode on potatoes; and at Aligarh, India, for nematodes attacking vegetables.

Federal scientific effort devoted to nematology research in FY 1964 included 2.5 man-years on citrus research; 0.2 on deciduous fruit and tree nut crops; 0.5 on flowers and ornamentals; and 2.2 on vegetables.

## PROGRAM OF STATE EXPERIMENT STATIONS

Nematology research programs are actively pursued in 47 States and Puerto Rico. Collectively, this well-organized research program is supported not only by the institutions involved, but also by such agencies as the National Science Foundation, National Institutes of Health, private institutes, foundations, and industry. Fundamental investigations in nematology continue to receive major emphasis by State scientists. Basic studies on the specifics of virus transmission by nematodes are being further investigated. Pioneering studies on the physiology and biochemistry of nematode pathogenicity, reproduction, and nutrition are contributing much new knowledge. A number of scientists are determining the actual biochemical specifics of nematode resistance in plants. Several nematologists are pursuing basic studies on the cytology and genetics of nematode species, particularly for Heterodera and Meloidogyne. Also refined serological techniques for use in identification of nematode species and races are being investigated. Research on many fungi, bacteria, and viruses as biological control agents has been intensified. Use of cultural and management practices in controlling a wide range of nematode types is to be studied to determine the effects of environment, soil, and plants on survival, reproduction, and losses. Many projects are also designed to determine the mode of action of specific chemicals on nematodes, and to determine the retention of these chemicals in plants and in the environment. Several scientists are concerned with more applied facets of research, which are of immediate use by extension, industry, growers, and the public in general. These studies include the development of nematode-resistant varieties, the evaluation of nematocides, and the development of practical crop rotations and sanitary practices. Cooperation and coordination of some of these research areas are facilitated by four Regional Research Projects in nematology and makes possible a network of effective research activity. Other facets of nematology research are reviewed in the appropriate crop sections of this reprint.

The research effort summarized herein is 54.9 man-years.

### PROGRESS - USDA AND COOPERATIVE PROGRAMS

1. Fruit crops including citrus. Citrus. Studies at Tempe, Arizona, indicate that control of the citrus nematode ( T. semipenetrans ) is not necessary or practical during the first several years citrus is planted because the unshaded soil with high temperatures apparently prevents increase of this nematode. Postplanting nematocide treatments with DBCP in irrigation water on both orange and grapefruit continue to show great promise. Yields of navel oranges were increased 37% in infected groves, and the number of premium grade fruit was increased by as much as 77%. A seven year study has shown that 4 gallons per acre of DBCP applied in irrigation water gives good nematode control for three or four years and that a two-gallon dosage must be repeated every other year to maintain normal growth of citrus in the presence of the citrus nematode. Studies in Florida show that the root-lesion nematodes ( P. brachyurus ) can withstand great extremes

of temperature and remain infective on citrus. They survived 37.7 hours of daily temperatures over 100°F during a 13-day period, and for 1.2 hours daily at a soil temperature of over 110° for 35 days. Statistical analysis of burrowing nematode (R. similis) data collected over a 10-year period in Florida indicate that nematode sampling in citrus groves is not accurate except in the cool fall, winter, and spring months when growth flushes occur on citrus, and when air temperatures range between 50° and 84°F. Surveys made over a 10-year period show that the citrus-root nematode (T. semipenetrans) occurs in all citrus areas of the Florida East Coast and occasionally on the Ridge area in the central part of the State. Chlorosis and decline in the East Coast area are often associated with water damage as well as the nematodes, which are thought to be responsible for as much as 25% yield losses. No effective control has been developed for this nematode in Florida.

Stone fruits. Dagger, root-lesion, and root-knot nematodes have frequently been associated with declining cherries in the intermountain area of Utah. Histopathological studies showed that the root-lesion nematode (P. minyus) causes extensive necrosis of root-tissue, and the root-knot nematode (M. hapla) produces conspicuous spindle-galls unlike galls produced by root-knot nematodes on other plants. Nematode problems of cherries in Utah appear to be severe.

Vegetables. Field evaluations at Tifton, Georgia, of combined uses of pesticides (nematocides, fungicides, herbicides, and insecticides) for control of multiple pest problems indicated that combination treatments were equal to or superior to each pesticide separately. Best production and pest control on tomato transplants were obtained by one application of a mixture of Shell SD 7727 (nematocide), Terraclor-Captan (fungicide), and Tillam (herbicide) by rotatilling the mixture to a depth of 6 inches 21 days before planting. Sub-surface blade application of a general soil sterilant (a mixture of DD + methylisothiocyanate) was superior to chisel-application giving equal nematode control at about half the dosage recommended for chisel-application. Several years research indicates that it is now possible to control nematodes, weeds, and soilborne diseases by pesticide combinations or by use of wide-range soil disinfestants. Experiments at Baton Rouge, Louisiana, have shown that the root-knot nematodes (M. incognita) cause severe losses to susceptible sweetpotato varieties. The nematode-susceptible variety 'Goldrush' produced 53 bushels of U.S. #1's and 2's compared to 230 bushels per acre of a resistant variety (L 9-39). Soil fumigation with a nematocide increased yield of the resistant selection by only 47 bushels; whereas, the yield of the standard variety was increased by 77 bushels indicating that the resistant selection gives substantial yield increases on land infected with root-knot nematodes. There is a growing horticultural practice for use of black polyethylene plastic as a surface mulch; however, research at Baton Rouge, Louisiana, indicates that the plastic covers increase field infestations of root-knot two-fold. Soil fumigation will probably be necessary when plastic mulches are used in the production of horticulture crops under plastic mulches. Cooperative studies with plant breeders at Louisiana State University indicate that the

tomato line L-125 is an unusual tomato variety, possessing resistance to the northern root-knot nematode (M. hapla) as well as to M. incognita, M. javanica, and M. arenaria. Other experimental lines were attacked by one or more root-knot species. Research in Peru, under a PL-480 project, has established new resistance to the golden nematode (Heterodera rostochiensis) of potatoes. The potato variety 'Shiri' was found in the mountains of Peru and appears to be highly resistant. This source of resistance will be valuable to worldwide breeding programs where golden nematode resistance is needed.

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##### Fruit

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## WEED CONTROL

### Crops Research Division, ARS

Problem. Weeds cause losses in crops, orchards, grazing lands, forests, water supplies, and irrigation and drainage systems. The control of weeds is often the most critical economic problem in many phases of agriculture. Improved weed control methods will facilitate farm mechanization, greatly increase production efficiency, and improve the efficiency of the use of human and land resources in agriculture.

### USDA AND COOPERATIVE PROGRAM

The U. S. Department of Agriculture has a continuing long-term program of basic and applied studies directed toward the solution of weed problems on farms. All the research on the control of weeds is conducted cooperatively with State Agricultural Experiment Stations with the exception of the research at Beltsville, Maryland; Denver, Colorado; and Mayaguez, Puerto Rico. State Agricultural Experiment Stations usually furnish office, laboratory, and field facilities, as well as funds and other assistance in support of the cooperative research. There is cooperation also with other Federal agencies. Industrial companies cooperate in furnishing experimental chemicals, equipment, and funds essential to rapid progress in weed control investigations.

There were 2.7 professional man-years devoted to weed control research in vegetable crops, and 0.3 to weed control in deciduous fruits and tree nuts.

### PROGRAM OF STATE EXPERIMENT STATIONS

All the State Experiment Stations are conducting basic and applied research in weed control. These studies involve evaluation of selective herbicidal properties of new chemicals to show the relation between chemical structure, herbicidal activity, and weed-crop selectivity; the nature, behavior, and effect of herbicides on their degradation products in and on plants and plant products; the mechanism of herbicidal action; influence of climate, plant morphology, and soil characteristics on the effectiveness of herbicides in selectively controlling weeds and on their persistence in plant tissue. The State Experiment Stations are directing a large amount of effort toward the development of practices for the selective control of weeds in crops, pastures, and rangelands. Studies are being conducted on the movement and persistence of herbicides in various soil types and the phenomena involved in absorption and other interaction of herbicides with clay complexes.

Weed life cycles and growth habits are being studied under different environments to determine the most susceptible stage of vulnerability to herbicides and other control measures. Other aspects that are currently

being investigated are: Competition between weeds and desired plant successions following control measures including replacement vegetation and management practices. Relation between weeds and biological control organisms that attack them in different environments is being studied on a limited scale.

Much of the basic research in weed control is being done via six regional projects as follows: W-52 is exploring the fundamental biochemical and biophysical processes involved in herbicidal action; W-77 is studying the chemical and physical properties of herbicides in relation to environment and effectiveness; NE-42 is investigating weed life cycles and light as factors in weed control; NC-61 is concerned with the nature and extent of competition between weeds and crops; S-18 and NE-42 are investigating the behavior of herbicides in soil, the physiological aspects of certain herbicides and life histories of important southern and northeastern weed species. CRF-1 program is attacking basic problems in aquatic weed control and brush control. The USDA cooperates on much of this research activity.

The total State scientific effort devoted to weed control research is 357.0 professional man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

1. Vegetable Crops. Preliminary evaluation of several herbicides on vegetables at Tifton, Georgia, has shown promising results on a number of crops. Vegetable legume crops were tolerant of N-(beta-0,0-diisopropyl=dithiophosphoryethyl)-benzenesulfonamide (R-4461), 4,5,7-trichlorobenz=thiadiazole-2,1,3 (TH-052H), and 3,4-dichlorobenzyl N-methylcarbamate (UC 22463A). Cucurbits were not injured by UC 22463A and R-4461. Okra tolerated TH-052H and UC 22463A.

In research conducted at Beltsville, Maryland, sodium and potassium azide were effective as soil treatments for control of mugwort (Artemisia vulgaris).

In a study of methods for controlling selected weed grasses and broad-leaved weeds in vegetable crops at Weslaco, Texas, it was discovered that under high soil temperatures, 1/2 lb/A of incorporated trifluralin was outstanding for control of Palmer amaranth (Amaranthus palmeri S. Wats), barnyardgrass and Colorado grass (Panicum texanum); 1/4 lb/A was satisfactory. Diphenamid failed even with incorporation. 2-chloroallyl diethyl=dithiocarbamate (CDEC) controlled broadleaved weeds only, required incorporation, and was completely deactivated after 3 weeks. White-surfaced asphalt enhanced surface-applied CDEC and diphenamid, decreased soil moisture losses but increased soil temperature and prevented seedling emergence with frequent irrigation.

- a. Asparagus. First yield results in long-term studies of the effects of herbicide use in asparagus plantings initiated in 1963 at New Brunswick, New Jersey, showed that annual applications of monuron, simazine, amiben, and linuron at herbicidal rates did not cause crop injury or yield reductions. Dichlobenil caused reductions in asparagus yields.
- b. Cabbage. In research on weed control in cabbage at Weslaco, Texas, it was found that DCPA, R-4461, and granular and liquid CDEC were selective in cabbage regardless of application method but were more effective surface-applied with rain. Only 1 1/2 lb/A of trifluralin injured cabbage when soil-incorporated 10 days before seeding; lower rates were selective.
- c. Carrots. Trifluralin was outstanding at Weslaco, Texas, for weed control in carrots with rain when soil-incorporated 22 days before seeding. Linuron and prometryne were satisfactory regardless of application method. CDEC controlled weeds selectively for a limited time with incorporation. 3'-chloro-2-methyl-p-valeritoluidide (solan) failed to control emerged weeds but injured carrots.
- d. Lettuce. At Weslaco, Texas, trifluralin was outstanding for weed control in lettuce with rain when soil-incorporated before or at seeding. R-4461 performed efficiently regardless of application method. CIPC performed better in soil surface applications but was mediocre. CDEC was not acceptable regardless of rate or method of application. Cultivation of soil before delayed seeding was ineffective.
- e. Onions. Incorporated applications were inferior to surface applications of DCPA at Weslaco, Texas, and injured the onions, as did incorporated CDEC. Only surface-applied CDEC was aided by oversprays of white-surfaced asphalt which decreased soil temperature and moisture losses.
- f. Peppers. Direct seeded peppers grown for transplanting at Tifton, Georgia, were shown to have a high tolerance to preemergence applications of amiben. Mixtures of paraquat and amiben or diphenamid at pepper emergence were highly effective. Propanil and diphenamid used alone at herbicidal rates injured pepper seedlings. Combinations of herbicides reduce total amount of herbicide needed.
- g. Pulses. At Beltsville, Maryland, twenty herbicides were evaluated on 12 pulse crops. Pigweed and ryegrass were satisfactorily controlled in all pulses by preemergence treatments with trifluralin, diphenamid, n-propyl-di-n-propylthiolcarbamate (R-1607), 2-chloro-N,N-diallylacetamide (CDAA), 2-chloro-N-isopropylacetanilide, and CIPC without critical crop injury. Trifluralin and diphenamid applied postemergence satisfactorily controlled pigweed and ryegrass in all 12 pulses without causing serious crop damage.
- h. Southern Peas. Preliminary research at Tifton, Georgia, has shown that southern peas will tolerate a number of preemergence herbicides if seeds are planted deeply enough.

i. Spinach. Granular and liquid CDEC and liquid PEBC were outstanding at Weslaco, Texas, for weed control in spinach when soil-incorporated. All herbicides but norea controlled weed best when incorporated 1 inch. CDEC controlled weeds more effectively but PEBC was the only herbicide that selectively controlled weeds when incorporated 1/4 in. at planting. A 10-day delay in planting provided selectivity with CDEC and CIPC incorporated 1 inch. Pyrazon and norea injured spinach at rates which controlled weeds.

j. Sweetpotatoes Slips and vine cuttings of sweetpotatoes were tolerant of herbicidally effective rates of diphenamid, amiben, R-1607, and EPTC at Tifton, Georgia. DCPA was effective on some annual weeds but caused undesirable stem proliferation. Preplant bed-over incorporation of low rates of R-1607 and EPTC caused crop injury. Results show real progress toward the development of effective weed control methods for sweetpotatoes.

k. Tomatoes. At Tifton, Georgia, applications of a combination of a small amount of paraquat, PEBC, and a suitable surfactant just before emergence of tomatoes in direct-seeded transplant beds effectively control germinating and young emerged weeds without crop injury. The combination of herbicides minimized the total amount of herbicides required. Diphenamid used separately as a preemergence treatment controlled weeds and was well-tolerated by the crop. At Weslaco, Texas, incorporated applications outperformed surface applications of trifluralin, diphenamid, CDEC, and PEBC in established tomatoes; no injury occurred where roots grew in herbicide-treated soil; the 0.5 lb/A rate of trifluralin was outstanding. Polyethylene appeared practical, but weed control was poor with petroleum-mulched, surface applications of PEBC. Preemergence, surface-applied diphenamid performed well with rain.

## 2. Fruit Crops.

a. Apples. Long-term research on the effects of repeated use of herbicides in apple orchards initiated at New Brunswick, New Jersey, in 1960 has shown that diuron used annually for five years did not cause visible injury symptoms or reductions in yield or quality of the crop. Simazine used annually for the same period showed a gradual diminution in herbicidal effectiveness suggesting that soil microorganisms that degrade simazine may be accumulating in the treated soil.

b. Blueberries. Long-term studies of the effects of repeated annual use of herbicides in blueberry plantings at New Brunswick, New Jersey, have shown that simazine and diuron used consecutively for 5 years gave excellent weed control without crop injury or yield reductions.

c. Cranberries. In long-term studies on weed control in cranberries at New Brunswick, New Jersey, it was found that dichlobenil applied after growth resumed in the spring caused marked reddening of the vine and reduction in fruit set. Dichlobenil is of value in cranberry culture because of its selective control of bracken fern.

d. Peaches. In New Brunswick, New Jersey, long-term studies of the effects of repeated use of herbicides in peach orchards begun in 1960 show that simazine used at herbicidal rates for five years did not cause visible injury or yield reductions.

3. Ornamentals. Long-term studies of the effects of repeated annual applications of herbicides on yew and Japanese maple were begun at Beltsville, Maryland, in 1964 to continue for a period of approximately 5 years. Rates of application include minimum herbicidally effective rates and much higher rates to determine the range of tolerance. High rates of some herbicides including diuron at 8 lb/A and DCPA at 40 lb/A have caused visible foliar injury to the maples after two annual treatments.

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##### Weed Control in Vegetable Crops

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##### Weed Control in Deciduous Fruits and Tree Nuts

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##### Weed Control in Ornamentals

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## EPIDEMIOLOGY OF PLANT DISEASES

Crops Research Division, ARS

Problem. Diseases cause annual losses estimated in billions of dollars. Fundamental to all applied aspects of disease prevention and control are the identity of the causal organism, its life cycle, epidemiology, ecology, and relationship to other organisms.

### USDA AND COOPERATIVE PROGRAM

The Department research is conducted at four locations. Identifications of plant pathogens and other fungi are made and the National Fungus Collections are maintained at Beltsville, Md. Taxonomic studies are made on parasitic leaf-and-stem fungi, wood-rots, and certain lower fungi important to grain storage.

Research is conducted on the epidemiology of tomato and potato late blight, bacterial spot of pepper and tomato, lima bean downy mildew, and yellow dwarf of barley to develop accurate plant disease forecasting methods. Epidemiological research continues in cooperation with the State Agricultural Experiment Stations at Raleigh, N. C.; Ames, Iowa; and University Park, Pa. The monthly "Plant Disease Reporter" emphasizes new records of disease occurrence, serious outbreaks, and new controls.

### PROGRAM OF STATE EXPERIMENT STATIONS

Many scientists at the State colleges and universities are actively engaged in research on the epidemiology of plant diseases. Collectively, these studies provide an extensive network of epidemiological investigations involving agronomic crops, horticultural crops, forest trees, specialty and drug crops, and disease problems associated with plants used in urban communities. In some cases these investigations are designed to provide information essential to the efficient use of specific chemical controls; whereas, in others it is needed to determine crop planting, harvesting, and other cultural practices. Some of these studies are designed to contribute fundamental information on such things as infection potential, interaction of climatic factors, microbial interactions, and in the development of epidemics per se. Over 50 of the State institutions in this country are involved in various phases of this work.

### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

1. Late blight of potato and tomato. In cooperation with the United States Weather Bureau, comparisons were made to determine whether data routinely recorded and reported by first-order Weather Bureau Stations could be used to indicate probable microclimatic conditions in potato fields in the north-central region. Paired values of relative humidity greater than 90 percent showed high correlations when the Weather Bureau Stations and the experimental weather-blight stations were near each other.

Dew recorders recorded duration of leaf wetness more accurately on outer upper potato leaves, which are exposed to sunlight and heat, than on inner lower leaves, which are protected and retain moisture longer. Accuracy in the latter location is increased when sensors are placed inside the foliage canopy.

The pathogenicity of Phytophthora parasitica, previously reported from the southeastern region as causing symptoms on potato leaves very similar to those due to the late blight species, P. infestans, was studied. Isolates of P. parasitica from tomato and from potato leaves and tubers, and of P. parasitica var. nicotianae, the black shank organism, from tobacco, were inoculated on tomato, potato, and tobacco plants. On foliage the black shank fungus was pathogenic only to tobacco. P. parasitica isolates from tomato and potato, in general, were pathogenic on tomato and potato, but not on tobacco, foliage. All isolates including those of the black shank fungus infected potato tubers. P. parasitica isolates infected tobacco roots but did not invade the stems to cause black shank symptoms.

2. Downy mildew of lima bean. Exposure to high temperatures (86° F and above) of Fordhook lima bean plants inoculated with Phytophthora phaseoli decreased the length of stem and leaf lesions in proportion to the elevation of temperature and the number of exposures. One 4-hour exposure to 86° or 89° did not significantly reduce the length of lesions as compared with the check; one exposure to 92° or 95° did significantly reduce length of lesions. At low temperatures (50° and below), there was little reduction in length of lesions with 1 to 7 exposures of 8 hours each to 50°. A definite reduction occurred from exposure to 45°. Still shorter lesions resulted from exposure to 40°, especially with the greater number of exposures.

3. Bacterial spot of pepper and tomato. Controlled experiments showed that the bacterial spot organism, Xanthomonas vesicatoria, overwinters in pepper plant tissues, including pods, stems, leaves, and roots, and that the infected plant material serves as source of infection for the succeeding season.

In 1963 Pseudomonas syringae was identified as the cause of a leaf spot of inoculated pepper and tomato plants, so closely resembling the leaf spot caused by X. vesicatoria as to be confused with it. Isolates of the North Carolina bacterium were compared with authentic P. syringae from various sources. Virulence differed somewhat among isolates, but all isolates infected all hosts inoculated. The comparison substantiates the identification of the North Carolina bacterium as P. syringae.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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## VEGETABLE INSECTS

### Entomology Research Division, ARS

Problem. The major objective of this research is to develop more effective, economical, and less objectionable methods of controlling insect and mite pests of vegetables in the field without leaving undesirable residues on or in the marketed product or in the soil, and without affecting the flavor or quality of the product, or adversely affecting beneficial insects. Insects and mites are important limiting factors in the production of high-quality vegetables. These pests reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase the cost of production. Use of insecticides and miticides is currently the most effective direct method of control; however, application too close to harvest may result in residue problems. There is concern over the possibility of contaminating animal products by feeding crop refuse or byproducts of peas, beans, sweet corn, or other vegetables treated with insecticides to livestock. Drift of certain insecticides into non-target areas also causes problems. Another difficulty is that a number of vegetable insects have developed resistance to certain insecticides. Research is needed on methods for better utilization of predators, parasites, and diseases of vegetable insects and mites; development and utilization of more effective traps and lures; new approaches to control including radiation, chemosterilants, and antimetabolites; evaluation of insecticide application equipment; and the practical integration of non-chemical and chemical methods in area control of vegetable insect and mite pest populations. Additional emphasis should be placed on research to develop vegetable crops resistant to insects and to determine the factors involved in resistance when found. Research is needed on insect vectors of vegetable diseases and the role they play in the dissemination of viruses. The heavy loss of corn due to corn stunt and maize dwarf mosaic recently in the Southern and North Central States indicates the importance of research in this field.

### USDA AND COOPERATIVE PROGRAM

The Department has a long-term program of applied and basic research on vegetable insects with stations at Mesa, Ariz., Riverside, Calif., Tifton, Ga., Twin Falls, Idaho, Lafayette, Ind., Baton Rouge, La., Beltsville, Md., State College, Miss., Wooster, Ohio, Forest Grove, Oreg., Charleston, S.C., Logan, Utah, and Yakima, Wash., in cooperation with the respective State experiment stations and industry. Much of the work is in cooperation with the Crops Research, Pesticides Regulation, and Agricultural Engineering Research Divisions. Work in Idaho is also cooperative with the Idaho Bean Commission and that in Maryland with the Northern Utilization Research and Development Division and the Human Nutrition Research Division. Work in Oregon is conducted jointly with the Agricultural Engineering Research Division. Work in Louisiana is under contract to the Louisiana Agricultural Experiment Station. Some of the work in Indiana is done by grant to the Agricultural Experiment Station.

Work was initiated in Karaj, Iran, on insects affecting vegetable legumes with funds supplied by the Agency for International Development (AID) under the grain legume production project in cooperation with the Crops Research Division, the Soil and Water Conservation Research Division, Karaj Agricultural College, the Iran Ministry of Agriculture and the Iran Plan Organization.

The Federal scientific effort devoted to research in this area totals 28.0 professional man-years. Of this number 4.0 is devoted to basic biology, physiology, and nutrition; 4.8 to insecticidal and cultural control; 3.7 to insecticide residue determination; 5.4 to biological control; 2.0 to insect sterility, attractants, and other new approaches to control; 1.5 to evaluation of equipment for insect detection and control; 4.0 to varietal evaluation for insect resistance; 1.3 to insect vectors of diseases; and 1.3 to program leadership.

In addition Federal support of research in this area under contracts and grants provides 1.7 man-years. Of this total, 0.3 is devoted to insecticidal and cultural control; 0.2 to biological control; 0.6 to insect sterility, attractants, and other new approaches to control; and 0.6 to varietal evaluation for insect resistance.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Research on vegetable insects at the State experiment stations is designed to provide both basic and applied information. Emphasis is being placed on developing methods for reducing the number of insecticide applications required for control. Population levels of injurious species necessary to cause economic damage are being determined. Insect predators and parasites are under investigation to determine what practices contribute to their increase. Microorganisms pathogenic to insects such as the polyhedrosis virus of the cabbage looper are being evaluated for their effectiveness. Fundamental studies on the influence of environmental factors on diapause, movement, and population size of injurious insects are being performed as methods for laboratory rearing of insects become more refined. Plant resistance and strip-planting of vegetables with other crops are promising areas under investigation. Methods of insecticide application which reduce the amount of chemical applied directly to the plant and the development of insecticides with greatly reduced residual properties are important current research areas. Studies also are being performed on the insect transmission of vegetable diseases.

The total State scientific effort devoted to vegetable insect research is 45.3 professional man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Basic Biology, Physiology, and Nutrition

1. Cabbage Looper Population Density and Migration Studies. The numbers of

cabbage looper moths caught in blacklight traps at Riverside, Calif., were low from November to mid-June. There followed a rapid rise to a peak catch of 31 moths per night per trap in August and a gradual decline thereafter to November. The male to female ratios of moths trapped varied considerably during the season, but the total catch was 53% males and 46% females. In general the number of matings per female increased as the proportion of males to females in the trapped samples increased. For the entire year females mated approximately 1.27 times but some mated as many as 6 times. Sixty-six percent of all female moths trapped during the year had mated at least once and 35% of these more than once. Male moths were trapped in greater abundance from midnight to 6 a.m. than from 6 p.m. to midnight. The reverse was true for females. The efficiency of blacklight traps in attracting cabbage looper males was increased from 12 to 37 times by virgin females of the species placed in cages adjacent to or in close proximity to the trap.

2. Flight Characteristics of Cabbage Looper Moths. A "flight mill" was successfully adapted for cabbage looper flight studies at Riverside, Calif. The equipment provides for automatic recording of the flight of moths fastened to a rotatable side arm. Total flight distance, time, and duration of flight and rest periods were determined. The flight distance of individual moths ranged from 0-120 miles. Maximum continuous flight time was approximately 7 hours during which the insect traveled 25 miles. The average velocity for all flying moths observed was 3 miles per hour with a maximum of 6 miles per hour. Moths 3 to 4 days old flew more consistently than moths 2 days old or less.

3. Salt Marsh Caterpillar Biology. Salt marsh caterpillars were reared on a modified semi-artificial medium successfully for 7 generations at Riverside, Calif. Pupation was over 90% for 3 generations, with 84 to 100% of the pupae producing normal moths, approximately 50% of which were females. Female pupae weighed more than male pupae. The viability of eggs from adults was low, ranging from 16 to 48%. Most matings occurred between approximately 3 a.m. and 5 a.m. Moth age was not a critical factor in determining mating and newly emerged to 4-day-old moths mated with equal frequency.

4. Adult Cabbage Looper Diets. At Riverside, Calif., moths fed 5, 10, or 15% aqueous solutions of galactose, dextrin, or lactose or 10% trehalose produced fewer eggs than moths fed solutions containing 5, 10, or 15% aqueous solutions of honey, levulose, dextrose, or sucrose. When moth pairs were fed maltose, the females laid more eggs than those fed sucrose; when fed honey solutions, the females deposited more eggs than those fed on other sugars. In general, moths did not produce more eggs nor was the viability increased with the higher sugar concentrations. However, moths fed 5% of dextrin or maltose laid fewer viable eggs than moths fed 10 or 15% dextrin or maltose. Moths fed 5% of galactose or dextrose laid more viable eggs than moths fed the higher concentrations of each sugar.

Longevities of male and female moths fed honey, levulose, dextrose, maltose, or sucrose were comparable at all concentrations. Moths fed any concentration of galactose, dextrin, lactose, or 10% trehalose were shorter lived than moths fed on other sugar solutions and in some cases they did not live as long as those fed water alone. When moth pairs were given only water, the females produced an average of 183 eggs per female, 52% were viable and longevity averaged 7 days. The females of moth pairs fed the more effective solutions of honey, levulose, dextrose, or sucrose laid from 419 to 642 eggs per female and lived 11 to 20 days.

5. Cabbage Looper Rearing Studies. At Riverside, Calif., at least 4 microbial contaminants were observed developing in the cabbage looper rearing medium where they reduced pupal yields. Formaldehyde, methyl p-hydroxybenzoate, n-butyl-p-hydroxybenzoate, sorbic acid, ottasept, pimaricin, vancomycin, and nystatin were evaluated as to their efficiency in reducing or eliminating contaminants on the medium and their effect on cabbage looper pupal yields and adult fecundity. Observations were made for at least 4 generations for each material tested. Microbial inhibitors must be effective for at least 14 days to be useful. Since each material was effective against some of the contaminants but not all of them, combinations of microbial inhibitors were necessary to effectively control all contaminants. The best antimicrobial combinations were n-butyl-p-hydroxybenzoate or methyl p-hydroxybenzoate (2,000 ppm in each case) plus sorbic acid (2,000 ppm). Combinations of ottasept (500 ppm) plus sorbic acid (2,000 ppm) or vancomycin (134 ppm) plus formaldehyde (370 ppm) were also effective in reducing mold contaminants for 14 days but may have retarded larval development.

Cabbage looper larvae were efficiently reared in 6- or 8-ounce paraffin-coated Lily cups. Approximately 24 larvae were reared per container at the total cost of about 0.3 cent per insect.

6. Mating Competitiveness Technique for Male Cabbage Looper Moths. In studies in California 11 water soluble fluorescent dyes were found that can be fed to male cabbage looper moths in sucrose solutions to make the spermatophores of the male easily identifiable in the female after mating. The dyes are Rhodamine B, methyl violet, eosin, Rhodamine 3 G0, Neutral Red Extra, pyronin, fluorescein, solium salt of fluorescein, brilliant phosphine, entozon, and primulin.

7. Caterpillar Pests of Leafy Vegetables in Arizona. At Mesa, Ariz., studies of flights of moths of the cabbage looper, alfalfa looper, beet armyworm, yellow-striped armyworm, corn earworm, and granulate cutworm are being continued on an annual basis by means of eight blacklight traps widely distributed within the cultivated area of the Salt River Valley and four similar traps in the desert areas surrounding cultivation. With the exception of the corn earworm, these noctuid moths have been taken in low but significant numbers throughout the entire year. Higher populations of noctuid moths occurred from January to March 1965 than for the same season in 1964. The difference in cabbage looper populations was far greater than

those for other noctuids. Winter rains germinated mustards in desert areas and indications were that a brood of cabbage loopers developed in the desert during January and February. From April to June populations of the cabbage looper were greater in the cultivated area than in the desert. During this period no known host plants of the looper occurred in the desert. These data indicate that the desert areas contributed cabbage looper moths to the cultivated areas only from January to March. Moths caught in desert traps later must have emerged in the cultivated area and moved out to the desert.

At Mesa, Ariz., marked moths were released periodically at 50, 100, and 200 feet from one 15-watt blacklight trap. Results showed that the recovery of cabbage looper moths dropped off rapidly between 50 and 100 feet with very few moths recovered at 200 feet. A greater percentage of beet armyworm moths than cabbage looper moths was recovered at 100 and 200 feet. Recoveries of armyworm moths were also comparatively low at 200 feet. These data indicate that the attractiveness of 15-watt BL to cabbage looper moths drops off rapidly between 50 and 100 feet but that the beet armyworm moths may be attracted to the light from a somewhat greater distance. Releases of marked moths in the four cardinal directions from one trap showed that although the moths flew in all directions there was a tendency for flight from south to north.

8. Blacklight Trap Study Area for the Cabbage Looper. Twenty-five 15-watt blacklight traps were installed over a 100 square mile study area southeast of Mesa, Ariz. These traps were placed at 2-mile intervals throughout the area and 16 points for release of marked looper moths were established at intervening locations. Rearing, marking, and releasing moths within this area to obtain basic data on flight behavior was commenced in June 1965. From the ratio of marked moths to native moths recovered, population estimates and flight behavior throughout the season will be derived. From these data, the feasibility of population suppression on an area basis may be indicated.

9. Southern Potato Wireworm. A total of 25,414 adults were caught in a single 15-watt BL trap operated throughout 1964 in coastal South Carolina. This constituted 98.4% of the total number of elaterid beetles taken. Conoderus falli composed 93% of larvae found in soil in 19 cultivated fields on 13 farms in October. Male sperms were found in females in spermatophores. Mating was observed during the afternoon. Very few adults were present or attracted to a BL trap in wooded areas. Only 6 beetles were taken in 3 traps located about 100 feet into woods between May 28 and June 21, as compared to 10,545 taken in 3 traps in nearby cultivated fields. Dipping of larvae in solutions of several proprietary tranquilizers, phenobarbital, and morphine sulfate and, in other tests, soaking the food in these solutions apparently did not reduce cannibalism among caged larvae.

10. Banded Cucumber Beetle. In South Carolina a feeding stimulant for the larvae was extracted from sweetpotato with water. The larvae preferred to feed on an agar-alphacel substrate containing a water extract of wheat germ

rather than on similar ones containing extracts of either corn meal, soybean meal, sweetpotato, or germinated corn kernels. A water-soluble substance that elicits a strong biting response in adults was extracted from 11 species of cucurbits (10 of Cucumis and 1 of Cucurbita), the most active extracts coming from Cucumis heptodactylus and Cucumis ficifolius.

11. Sweetpotato Insects. Larvae of the banded cucumber beetle and the pale-striped flea beetle caused 71% of the insect injuries to sweetpotato in Louisiana in 1964. In cage studies much of the injury caused by these two species was indistinguishable. Relatively high populations of banded cucumber beetle larvae were found as late as mid-January 1965 and adults were abundant at this time. A survey of wireworm populations in sweetpotato soils disclosed that Conoderus vespertinus was the most abundant, followed by C. bellus and C. falli.

12. Sweet Corn Insects. At Tifton, Ga., a vitamin preparation commonly used in artificial diet for rearing lepidopterous larvae was found to be deficient in two vitamins, folic acid and vitamin B<sub>12</sub>, when used in a fall armyworm diet. The substitution of another vitamin mixture containing the two vitamins in sufficient amounts has almost entirely eliminated insect deformities experienced in previous attempts to rear this insect. In addition, it has reduced the erratic and extended insect life cycle, increased the stability of the diet to breakdown by oxidation, increased production, and reduced costs (not only by the above factors, but also by reducing cannibalism which allows more insects to be produced with the same amount of labor and materials).

Entomologists in cooperation with agricultural engineers have developed two devices that facilitate the rearing of lepidopterous larvae on a large scale. One device uses air pressure to dispense large quantities of agar-base insect diet into individual rearing containers. The second is a machine that transports containers of insect diet beneath a venturi component where larvae are picked up and deposited onto the diet.

Research on the theory that insects locate and communicate by means of infrared and microwave radiation has continued at Tifton, Ga. Experiments with flight activity of noctuid moths under different lighting conditions have shown that mating is highest with ultraviolet and cool-daylight fluorescent lights alternating with darkness. The results indicate that conditioning the insects with ultraviolet and visible radiation contribute to their efficiency in receiving infrared and microwave radiation in darkness.

An infrared blackbody was constructed which eliminated all visible light but allowed radiation of secondary emission in the 8  $\mu$  to 13  $\mu$  region. Six different species of noctuid moths were attracted to the radiating blackbody in a totally dark room, whereas nonemitting blackbody controls did not attract any moths.

13. Pea and Bean Insects. In experimental plantings of vegetable legumes initiated at Karaj, Iran, the pea aphid was one of the first insects to cause injury, followed by the dipterous leaf miner, the pea weevil, the beet armyworm, and the corn earworm. The green peach aphid was also present. Pea varieties Ride de Knight and Morses Progress showed some evidence of resistance to the pea aphid.

#### B. Insecticidal and Cultural Control

1. Corn Earworm in Sweet Corn. When 19 sweet corn varieties were treated with five applications of DDT at 2 pounds per acre and graded for corn earworm damage at Tifton, Ga., little improvement was shown in insect control in varieties known to be resistant. The most susceptible varieties showed the greatest responses to DDT. Each of the following compounds applied at 1 pound per acre gave corn earworm control as good or better than 2 pounds of DDT per acre: SD-9129 and SD-8447, Mobil Oil MCA-600, Niagara NIA-10242, UpJohn U-12927, Stauffer R-5092, and General Chemical GS-4072.

2. Beet Leafhopper. Dimethoate and mevinphos continued to reduce the incidence of curly top in small field plots of beans in Idaho and increased yields. By caging viruliferous leafhoppers on the plants it was demonstrated that mevinphos was the more effective 1 day after application but that dimethoate is more effective 7 and 14 days after application. In laboratory tests with 68 materials, promising results were also obtained with Zinophos, Perthane, and 4 experimental insecticides.

In experimental plots of tomatoes at Farmington, Utah, mevinphos or Di-Syston granules added to the row at the rate of 4 pounds per acre at the time of transplanting reduced curly top 75% over the untreated checks.

At Santa Clara, Utah, experimental plots of tomato transplants receiving five foliar applications of dimethoate emulsion at the rate of 1 pound per acre showed 86% less curly top than the untreated checks. Dimethoate granules added to the plant holes at the time of transplanting reduced curly top 50% in curly-top-susceptible varieties and 88% in curly-top-resistant varieties.

3. Wireworms. In Washington 90% of sugarbeet wireworms confined in soils treated with 4 pounds per acre of parathion or diazinon (in granules) died within 14 days. In field experiments broadcast applications of granular diazinon or parathion at recommended dosages were usually effective against the sugarbeet wireworm, the Pacific coast wireworm, and the Great Basin wireworm, but control was more consistent with parathion than diazinon.

4. Sweetpotato Insects. In Louisiana plastic mulch barriers reduced insect injury to the roots of sweetpotato by approximately 20% but tended to increase injury caused by the sweetpotato weevil. Banded cucumber beetle larvae caused more damage to sweetpotatoes growing in fertilized than in unfertilized soil.

In South Carolina field experiments, diazinon and Stauffer N-2790 gave the most effective control of an insect complex consisting of the southern potato wireworm, the banded cucumber beetle, the spotted cucumber beetle, the elongate flea beetle, a related flea beetle (Systema frontalis) and an Anthicid (Notoxus calcaratus). Next best control was provided by a preplanting broadcast application of DDT. About 50% of the damage was caused by the wireworm.

In the laboratory in South Carolina, 39 experimental insecticides were screened against the banded cucumber beetle and 28 against the southern potato wireworm. Several of these materials have continued to show promise in field tests against wireworms. Laboratory tests revealed that larvae of southern potato wireworm developed approximately 4-fold resistance to parathion in the field between 1960 and 1964. No change in susceptibility to DDT or diazinon was apparent. Parathion and diazinon were as toxic to larvae of the gulf wireworm as to those of the southern potato wireworm in laboratory evaluations.

5. Dichlorvos Granules. Experimental granules of dichlorvos, prepared by impregnating corncobs or coarse vermiculite, retained activity for 42 months more efficiently than granules prepared on fine vermiculite, Attapulgit, or Diatomite. The fresh granules were equally toxic to drosophila, the green peach aphid, mealy bugs, and spider mites in these Maryland studies.

### C. Insecticide Residue Determination

1. Undiluted Technical Malathion Spray. Laboratory tests at Beltsville with malathion (technical) applied undiluted in comparison with oil solution and water emulsion, each with 8 ounces malathion per acre, showed highest initial deposits ( $6 \text{ mg/cm}^2$ ) and longest persistency (0.5 mg at 12 or 15 days) from the undiluted technical material. Initial deposits from malathion in oil and malathion emulsion were lower ( $4.5 \text{ mg/cm}^2$ ) and had shorter persistency (0.5 mg in 4 days). In field tests with low volume sprays on spinach near Vienna, Md., undiluted technical malathion applied with the Yoeman nozzle persisted for 4 days with 1.8 ppm residue from 8 ounces per acre and 37 to 61 ppm residue from 16 ounces. Malathion from conventional emulsion spray applied at the same dosages completely disappeared during the 4-day period.

2. Diazinon on Greenhouse Tomatoes. In Maryland a spray prepared from a 25% diazinon emulsion concentrate was applied at the rate of 1 pound per acre. Samples of tomatoes collected the same day they were sprayed contained 0.43 ppm of diazinon. The residue decreased to 0.37 ppm by the second day and to less than 0.2 ppm by the fourth day after treatment.

3. Chlordane Residues from Soil Treatments. In Maryland, chlordane was applied to sassafras sandy loam soil at  $1\frac{1}{4}$ ,  $2\frac{1}{2}$ , 5, and 10 pounds per acre before planting 10 vegetable crops. This range included all dosages recommended for all soil pests. Strawberries, tomatoes, and snap beans grown in this soil had residues of less than 0.01 ppm, which is the minimum

detectable level. Turnips, turnip tops, table beet tops, cantaloup, sweet-potatoes, Irish potatoes, and lettuce contained residues between 0.01 and 0.1 ppm. Beets and cucumbers grown in soil treated with 10 pounds of chlordane per acre contained residues of 0.15 and 0.11 ppm, respectively. Soil samples collected 127 days after treatment contained 0.16, .33, .58, and 1.1 ppm of chlordane for the different dosages, respectively.

4. Residues in Sweetpotato. Analyses by ARS chemists in Maryland showed no excessive residues of aldrin or dieldrin on or in roots of sweetpotato grown in South Carolina in field plots that received the following treatments: Dieldrin at 1.5 and at 3.0 lb/acre prior to planting; dieldrin at total of 1.6 lb/acre in 2 applications at base of plants during root enlargement; chlordane at 5 lb/acre prior to planting. Dieldrin residues ranged from 0.01 to 0.04 ppm and chlordane from 0.03 to 0.11 ppm.

Granular diazinon applied to the soil in sweetpotato plots at 3 pounds per acre once or twice during the period of root enlargement did not result in measurable residues in harvested sweetpotatoes.

5. On Sweet Corn. Entomologists and chemists at Tifton, Ga., determined residues of Shell SD-8447 applied to sweet corn as a wettable powder at  $\frac{1}{2}$ , 1, and 2 pounds per acre. Electron affinity gas chromatography analysis revealed that initial residues on the stalks and leaves were about the same as those on ear husks. However, the residues on the husks diminished faster. The level of residue on both plant parts varied directly with the quantity of insecticide applied. After 16 days of weathering only 0.42 ppm of the insecticide remained on the stalks and leaves, and 0.02 ppm on the ear husks in plots treated with the 2-pound rate. No detectable residues were found in the ears after 16 days weathering in the field.

6. Residues on Greenhouse Vegetables. Analysis by chemists in Maryland showed 9.9 ppm malathion on greenhouse lettuce 10 days after spraying with  $1\frac{1}{4}$  pounds of malathion per 100 gallons of spray. After 14 days the residues had decreased to 2.6 ppm. On similarly treated cucumbers the residue of malathion was less than 1 ppm 2 hours after spraying.

On greenhouse tomatoes a residue of 0.7 ppm was found 3 and 7 days after spraying with 1 pound of tetradifon per 100 gallons of spray. No excess residues were found after spraying the tomatoes with 2 pounds of Kelthane per 100 gallons.

#### D. Biological Control

1. Sweet Corn Insects. At Tifton, Ga., the nuclear polyhedrosis virus of the corn earworm was used in an early season field trial on sweet corn in which the virus alone and in combination with DDT was compared with a DDT standard and an untreated control. The best control was obtained with a combination of virus and DDT applied at the early-tassel treatment and at 3-day intervals during silking. There was no significant difference between

(1) DDT alone applied in the tassel stage followed by treatments at 3-day intervals in the silking stage, (2) the virus alone applied in the tassel stage followed by treatments at 3-day intervals during silking, or (3) a single virus treatment applied during the tassel stage. All were significantly better than the untreated control.

2. Sweetpotato Insects. In South Carolina the nematode DD-136-bacterium complex caused 59% mortality of the southern potato wireworm within 7 days in soil cages. A spore suspension of the sporozoan, Mattesia grandis, was not effective against the banded cucumber beetle.

3. Cabbage Insects. In further field studies in South Carolina, weekly applications during the fall of 1964 of a commercial Bacillus thuringiensis wettable powder reduced to 13% the proportion of cabbage damaged by the cabbage looper compared to 56% damage to untreated plants. Addition of mevinphos to this pathogen was of no significant value. The B. thuringiensis was essentially as effective as mevinphos, endosulfan, or parathion but none of these materials, as used, gave adequate protection against the cabbage looper. The powder formulation of the pathogen was more effective than a commercial liquid formulation. In other field tests polyhedrosis virus at 1,000 billion polyhedra per acre or 1.2 lb/acre of a commercial B. thuringiensis powder, or both, applied 3 times to heading spring cabbage allowed 25.6 to 90% of the plants to become damaged by the cabbage looper. A suspension of a nuclear polyhedrosis virus stored for 10 months at room temperature was ineffective against third-instar cabbage loopers. Portions of this suspension kept refrigerated (at about 40° F.) or frozen were highly infectious.

In California single applications of cabbage looper nuclear polyhedrosis virus suspensions at 1, 2, or 4 hundred billion polyhedra per acre, or sprays of 0.5, 1, or 2 pounds per acre of B. thuringiensis containing  $2.5 \times 10^{10}$  spores per gram were not sufficient to give adequate protection during the season. Weekly applications of virus suspensions containing 2 or 4 hundred billion polyhedra per acre resulted in an average of 73-74% reduction of cabbage looper larvae after the second application. Similar larval reductions after weekly applications of B. thuringiensis spray at 2 pounds per acre did not occur until after the third weekly application when it gave good control.

In California 53 pathogens were evaluated for effectiveness against corn earworm larvae in laboratory tests. Mortalities of corn earworm larvae within 4 days after treatment ranged from 80 to 100%. The source of these pathogens was the collection of the University of California.

Cabbage looper virus preparations were produced in large amounts for field and basic laboratory studies at Riverside, Calif. Larvae were reared on an artificial diet. Efficient methods of inoculation and harvesting of the virus have been developed.

Tachinid flies, Voria ruralis, were produced in the laboratory at Mesa, Ariz., by exposing half-grown cabbage loopers reared on a defined diet to the flies. Puparia thus produced were accumulated under controlled temperatures of 45 to 50° F. Loopers were introduced into large field cages 12 X 24 X 6 feet and tests were made to determine the effectiveness of introduction of flies or puparia of V. ruralis. Each cage contained 120 lettuce plants; each plant was infested with two first or second instar loopers. Introduction of 24 pairs of flies produced 75% parasitism; introduction of 20 puparia produced 57% parasitism.

4. Pea Insects. Aphidius smithi Sharma & Subba Rao, a parasite of the pea aphid, Acyrtosiphon pisum (Harris), imported from India and released in the Pacific Northwest in 1959 and 1960 has become established and consisted of 3% of all parasites reared from aphids collected throughout eastern Washington in 1964. This parasite also survived the severe winter of 1964-65. It is more prolific than either of two native parasites. Hot, dry weather in the major alfalfa and pea production districts of eastern Washington during July and August of each year reduces the population of the pea aphid, Acyrtosiphon pisum (Harris), to extremely low population densities. Several large cages were transported to a small alfalfa field at the 2,500-foot elevation in the Cascade Mountains for pea aphid parasite production in late June 1964. Approximately 270,000 parasites, chiefly Aphidius pulcher Baker, were produced and later transported to alfalfa fields near Walla Walla, Wash., in September after the pea aphid had started propagating again. Based on the relatively high ratio of parasites to aphids in alfalfa fields in the spring of 1965, this operation was of considerable importance in control of the aphid on peas.

A 9-month survey of seed and forage alfalfa fields at Walla Walla, Wash., in 1964 showed that whereas the pea aphid, Acyrtosiphon pisum (Harris), averaged over 7,000 per 100 sweeps on February 2, from 1,100 to over 6,000 through March, and populations increased to a seasonal peak of 70,000 in forage fields April 16, their numbers declined rapidly thereafter and became rather scarce through October. Parasites and several kinds of predators increased slowly and some species were rarely found until June. Coccinellids were present by mid-March, aphid parasites, lacewings, spiders, syrphids, anthocorids, and geocorids appeared early in April. Populations of adult aphid parasites increased erratically through April, May, and June and were most numerous in late August, September, and October. Several kinds of predators also were most abundant late in the season after the aphid population had declined sharply.

5. Beet Leafhopper. Increasing evidence was obtained that it is practical to control this lone vector of the destructive curly top disease in the whole of southeast Idaho by use of crested wheatgrass and controlled range management. During the spring of 1965 the movement of the leafhopper from desert breeding areas to cultivated areas was one of the lowest on record. Only 10 to 20 leafhoppers were found per 100 feet of sugarbeet row. This low population of the leafhopper is attributed to the planting of much of

the acreage of its key host plant, Russian-thistle, to crested wheatgrass followed by controlled grazing. This project, initiated in 1959 in cooperation with the Bureau of Land Management, Department of the Interior, to replace 300,000 acres of Russian-thistle with permanent range grass, is showing rapid progress. An excellent stand of crested wheatgrass is well established on more than 100,000 acres of the more important breeding areas of the insect.

#### E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sex Lure in Banded Cucumber Beetle. Studies in South Carolina of the sex attractant of this cucumber beetle were expanded in cooperation with ARS chemists at Beltsville, Md. Twenty-one synthetic compounds and 68 chromatographic fractions of the natural female lure were bioassayed as male attractants. Several of these proved quite effective. Extracts of the abdomens of at least 32,372 virgin females of banded cucumber beetle adults were sent to Beltsville, Md., for fractionation. Sticky-board traps baited with the natural female lure caught approximately 87% of the males in a one-fourth acre field plot of tomatoes within 30 hours. Some substance in the flowers of plants, probably pollen, seems to be needed for females of spotted cucumber beetles to produce a male attractant. Male banded cucumber beetles did not respond to extracts of spotted cucumber beetle.

2. Sterilization of Banded Cucumber Beetle. In laboratory studies in South Carolina metepa-fed female adults of the banded cucumber beetle laid significantly fewer eggs than untreated ones. Apholate, metepa, and tepa fed to male adults gave significant but varying degrees of sterility. Fresh residues of 0.25% and 4% apholate on glass were highly effective; 1- and 4-day-old residues were only partially effective. No appreciable mortality was noted when males were exposed 1 to 60 minutes to dried 4% apholate residues on glass. Residues of 4% apholate on plastic were highly effective, but very toxic to the insects; those of 2% apholate were only partially effective. A dried residue of 8% apholate on glass was highly effective in sterilization of males.

3. Sterilization of the Cabbage Looper. In California the treatment of cabbage looper pupae with acetone or water solutions containing various concentrations of tepa up to 4% induced a high degree of sterility in male moths. Female pupae were less susceptible to the treatment and concentrations up to 12% in water or 50% acetone did not result in over 55% reduction in the number of viable eggs produced by mated females. Male cabbage looper moths fed .5 or 1% tepa in 10% sugar solutions mated less, longevity was reduced, and the number of copulatory aberrations increased. Males sprayed with .5% aqueous tepa solutions lived as long and mated as frequently as untreated males. Tepa fed moths did not respond to female pheromone extracts in bioassay tests in the same degree as untreated males. The responses of tepa-sprayed males were comparable to those of untreated males. A male cabbage looper moth sterilized with tepa is capable of mating with and transferring sperm with dominant lethals to at least 4 females. The testes

of mated or unmated male moths treated with 1 or 2% tepa showed a slight decrease in size which became more evident as the interval after treatment increased. Unmated tepa treated females deposited few eggs and dissections at various times after treatment showed the presence of variable numbers of fully developed eggs in the ovarioles of both treated and untreated groups. However, in mated females, the numbers of eggs per ovariole decreased as the time after the treatment increased. This indicates that the development of the ova at the time of treatment is an important factor in determining the effects of the chemosterilant treatment on the reproductive tissues of the females. Apparently a number of eggs in the ovarioles of females less than 1 day old, though not mature, are advanced enough in development so that irrespective of chemosterilant treatment, these continue to form the chorion and are laid by the treated female. Once these eggs are laid, eggs in the earlier stages of development at the time of treatment are prevented from further development. Sterile males or sterile females confined in cages with untreated male and female moth populations reduced the reproductive potential of the untreated population. At ratios of 10:1:1, sterile males or females to normal males and females, respectively, the reduction in numbers of larvae produced was over 90% as compared to check treatments. The effect of sterile males and sterile females was additive in this respect.

4. Drosophila Sterilization. In Maryland a high degree of sterilization of drosophila flies in tomato field plots was accomplished by distributing 2% apholate or 3% ENT 50905 in baits on coarse vermiculite or oasis cubes, or in protected glass jars. Eggs laid by females collected from the experimental plots yielded 50% fewer progeny than eggs laid by females collected from untreated tomatoes 1.5 miles distant from the experimental field. Of females collected from apholate-treated plots, a maximum of 81% were sterile. Differences between treatments in these experiments were reduced by extensive interplot movement of flies over 50-foot interplot spacing which was shown by high sterility of female flies collected from untreated check plots.

In laboratory studies at Beltsville, normal male drosophila flies showed no mating preference between untreated females and females sterilized by exposure to 16 kr of cobalt-60 radiation. In other experiments the introduction of irradiated (16 kr) male drosophila flies into a population of untreated flies suppressed the reproductive potential more than did the introduction of a like number of sterilized female flies. The same degree of sterility was attained when only sterilized males were introduced into the population as when the same number of sterilized males with associated sterile females were introduced. According to these studies no increase in efficiency of a sterile male release program would result by sexing Drosophila melanogaster to remove the majority of females from treated males before release.

Of 55 samples screened as baits for drosophila flies at Beltsville in 1964, none approached the attractiveness of the so-called Beltsville standard bait containing 10% granulated sugar, 4% dry yeast, and 1% cider vinegar, in water. However, addition of 5% glycerin doubled the attractiveness of this bait, probably because of the hygroscopic qualities of glycerin that slowed the

drying out of the original bait and the loss of attractiveness. ENT 50905 at 1% concentration in the standard sugar-yeast-water bait gave high sterility of male drosophila adults for about 2 weeks. Some males showed considerable rejuvenation after this period whereas apholate-treated flies remained sterile for life.

5. Aluminum Mulch for Aphid Control. In experiments at Deerfield Beach, Fla., conducted by Beltsville, Md., and Farmingdale, N.Y., laboratories in cooperation with Florida Agricultural Experiment Station, soil mulch of reflective aluminum foil and black plastic on plots of straight-neck bush squash, planted January 15, aphid-transmitted watermelon mosaic virus infection appeared earlier in unmulched check plots. Aphids flying into the plots were reduced 90% by the aluminum mulch and 29% by the black plastic. At the end of March, 4 weeks after beginning of harvest, 68.5% of check plants were virus infected compared to 51 and 4.1% in black plastic and aluminum mulches, respectively. Although virus infection increased rapidly in April, late infected aluminum-mulched plots produced marketable fruits. In continuing experiments at Beltsville in the spring of 1965 on summer squash, reductions of 75 and 37.5%, respectively, of aphid-transmitted virus infections resulted in plots mulched with aluminum and black plastic, when compared with unmulched check plots.

6. Sweet Corn Insects. At Tifton, Ga., testing of ether extracts from the virgin fall armyworm, Spodoptera frugiperda, corn earworm, Heliothis zea, and true armyworm, Pseudaletia unipuncta, moths has shown that a specific mating stimulant (sex pheromone) is produced by the female of each species. In all three insects the lure was found within the last two abdominal segments. Attempts to recover the pheromone from heads, thoraces, and/or upper abdominal segments have failed. When male fall armyworm moths, 3 to 6 days old, were exposed to 0.2 equivalent of females of different ages, only 2% of the males reacted to extracts of females 12 hours old, 32% reacted to extracts of females 24 hours old, 80% to females 36 hours old, and 98% to females 48 hours old. When 3- to 6-day-old males were exposed to varying concentrations of extracts on 3-day-old females, 98% of the males reacted to 0.02 female moth equivalent (FME), 88% reacted to 0.002 FME, 66% reacted to 0.0002 FME, and 20% reacted to 0.00002 FME.

#### F. Evaluation of Equipment for Insect Detection and Control

1. Suction Fan in Light Traps. In field studies in South Carolina a suction fan in a 15-watt blacklight trap tended to reduce the catch of adults of southern potato wireworm and increase that of adults of corn earworm, cabbage looper, and 2 species each of armyworms and of cutworms.

2. Insects Attacking Sweet Corn. At Tifton, Ga., agricultural engineers worked with entomologists and pesticide residue chemists to develop a high clearance tractor-mounted revolving brush applicator to treat corn silks for corn earworm control. Applications at the rate of 1.3 pound per acre produced two to four times more insecticide residue on ear tips than emulsion

sprays applied at the rate of two pounds per acre. The brush applications resulted in as good earworm control as that obtained with emulsion sprays.

3. Applicator for Low Volume Sprays on Small Plots. In field tests in Maryland, progress was made in the development of a simple sled-type unit for applying ultra low volume sprays to small plots of row crops. The undiluted liquid insecticide is discharged from a paint sprayer or mixtures with Freon are discharged from pressurized containers. A plastic hood confined the insecticide particles around the plants.

4. Spray Deposit Pattern of ARS Bell 47 D-1 Helicopter. The spray deposit pattern curves for tests conducted by entomologists and agricultural engineers in Oregon using a symmetrical arrangement of spray nozzles with either D8-56 or D6-46 orifices on a 26-foot boom mounted both in the forward and amidship positions moving at 30, 45, and 60 mph gave the following information: (1) At the 5-8 foot flight elevation: (a) The swath widths measured at the mean deposit rate level were all approximately 40 feet; (b) all pattern curves showed a zone of low deposit located from 4 to 10 feet right of center and second low deposit zone was 5 feet left of center--the general shape of the curve was pyramidal. (2) At the 20-25 foot flight elevation: (a) The application swath was approximately 5 feet wider than for the lower flights; (b) the overall shape of the patterns was the same as for the lower flight levels; and (c) height of flight made no appreciable difference in pattern shape due to boom location or speed of application.

The pattern studies for tests conducted with a 48-foot boom mounted both in the forward and amidship positions showed that: (1) At all flight levels the swath widths were increased by an amount equivalent to the increased boom length; (2) speed and boom location had no bearing on swath width; (3) the location of the low deposit zones was approximately the same as for the shorter boom; (4) the deposit curves for the 20-25 foot application height were more trapezoidal in shape; and (5) the most reasonably uniform deposit pattern curve was obtained with the forward mounted boom, a 60 mph application speed and the 20-25 foot application height.

In studies of spray coverage on pole beans from applications with the spray boom mounted on the front ends of the skids and carrying 27 symmetrically-spaced nozzles, the mean recovery rate of spray deposited on Mylar tape at the 6-foot level was 2.78 gpa on the upper leaf surfaces and 0.44 gpa on the under leaf surfaces. Similar results were obtained at the 4-foot and 2-foot levels. The spray deposits on the upper leaf surfaces at the  $\frac{1}{2}$ -foot level averaged 51% of those recorded at the 6-foot level, while under leaf deposits at the  $\frac{1}{2}$ -, 2-, 4-, and 6-foot levels ranged from 15 to 16% of that at the upper leaf surfaces.

The Bell 47 D-1 was used to determine the effects of spray coverage penetration when applications were made to corn at high (57 mph) and low (30 mph) speeds at 3 to 5 feet above the plant canopy. Analysis of the spray deposits showed that the gallonage rates on the upper leaf surfaces from applications

at 30 mph were approximately twice the rates recorded at 57 mph. At the higher discharge rate and slower speed, the under leaf surface deposits were about the same for the 2 speeds with the exception of that at the  $\frac{1}{2}$ -foot level where 67% more spray was recovered from application at the slower speed.

5. Marking of Forest Trees for Spray Operations. A portable unit for marking forest tree tops was developed in Oregon in cooperation with the Forest Service. It consisted of an air pressure and paint supply tank mounted on the side of the ARS Bell 47 D-1 helicopter. A hose line, controlled by a valve, led to a  $\frac{1}{2}$ -inch I.D. boom, 8 feet in length, mounted on a bracket at the forward tips of the landing skids. This boom extended outward in front of the pilot with a tee section about 2 feet long on the end with 3 Spraying Systems Co. diaphragm nozzles. Orange latex marking paint was used in the tank and pressurized with air to 100 pounds. The marking was accomplished by flying to the desired tree top, momentarily hovering over the tree, and spraying about one pint of the bright orange paint on the tree top. The helicopter must be capable of hovering at density altitude for use of this method.

6. Aerial Spray Drift. In Oregon, preliminary studies on spray drift from the ARS Rawdon T-1-250 low-wing monoplane showed that spray trapped in the wingtip vortices was drawn through the air after the spray boom had been shut off at the end of a spray run. More spray was carried farther in a straight flight after cut-off than when the spray cut-off occurred before pull-up. The chance of spray entrainment was enhanced when the spray was cut off during pull-up. Measurable amounts of spray were recovered on the ground for 500 feet past the cut-off line.

#### G. Varietal Evaluation for Insect Control

1. Sweetpotato. In continued laboratory and field studies in South Carolina, Louisiana breeding line L3-64 again proved outstanding in resistance to soil insect attack, receiving little or no economic damage under conditions where several leading commercial varieties would have had to be drastically culled to be marketable. L3-64 was resistant to injury by the southern potato wireworm, sweetpotato flea beetle larvae, a white grub, and a Diabrotica-Systema species complex. Other breeding lines under study showed significant degree of resistance to one or more of the insect species and some were especially susceptible to certain species. None of the varietal characteristics considered were found to be clearly associated with resistance to the insects involved. Attempts to develop a laboratory technique for screening a large number of sweetpotato breeding lines or varieties for their degree of resistance to soil insect injury were only partially successful.

Field-plot evaluations of 64 varieties or breeding lines in Louisiana indicated considerable differences in their susceptibility to insect attack. An attempt to develop a method of screening candidate lines for insect resistance in greenhouse benches yielded promising results.

2. Cabbage. Exploratory field studies in South Carolina indicated that significant resistance to cabbage looper injury existed among 13 breeding lines and several commercial varieties of cabbage. No differences in rate of development of the larvae on a green and a red variety of cabbage were apparent.

3. Sweet Corn. Preliminary field tests in 1964 at Tifton, Ga., indicated that the planting dates of sweet corn influenced the amount of corn earworm damage with either natural or artificial infestations. Generally, there was less damage with good growth conditions. Since the lack of an adequate earworm infestation can give a false indication of resistance, natural infestations were not as reliable as artificial infestations.

Field cage studies showed that fewer earworm larvae could establish on unpollinated silks than on pollinated silks, indicating that either pollen itself or the physiological or physical changes in silks initiated by fertilization helped larvae to become established.

Although slitting the husk of a resistant sweet corn inbred increased earworm damage, some factor or factors other than husk tightness contribute to resistance. Injury was not as great in resistant lines with slit husks as in susceptible inbreds with slit husks.

Six Southern Grain Insects Research Laboratory inbreds have indicated good resistance and quality in a hybrid testing program. Backcrosses of the inbreds in Walter's White have shown increased inbred vigor and maturation, yet little of the earworm resistance or quality has been sacrificed.

At Lafayette, Ind., 26 sweet corn inbreds, 51 experimental sweet corn hybrids, and 6 commercial sweet corn hybrids were grown and evaluated for earworm resistance. In general, it was found that longer husk extensions were associated with less earworm injury, although not in every case. Relatively short husk extensions were not always associated with susceptibility to the earworm. Twenty-seven of the experimental hybrids were more resistant than the most resistant commercial hybrid.

#### H. Insect Vectors of Diseases.

1. Bean Insects. In 9 series of trials at Yakima and Prosser, Wash., 15 to 30 viruliferous six-spotted leafhoppers, Macrosteles fascifrons, were placed on each of 218 bean plants and allowed to feed for 7 to 21 days. This attempt to transmit a Washington strain aster yellows from Erigeron canadensis to Red Mexican beans failed.

In Washington a study of possible virus vectors on beans showed the intermountain leafhopper to be the most abundant followed in order by the six-spotted leafhopper and the beet leafhopper. Eleven species of leafhoppers were found on beans and 13 on nearby clover. Nine species of aphid were

found on beans, 8 of which were collected only in the winged form. The pea aphid, the English grain aphid, and the green peach aphid were the most abundant.

2. Sweet Corn Insects. Cooperative research by State and Federal entomologists and pathologists have shown that the disease infecting corn in the South and Midwest since 1962 is due to two separate viruses. The one in the South is a persistent leafhopper-transmitted virus known as corn stunt while the one in the northern area is a non-persistent virus, now named maize dwarf mosaic, which can be transmitted by aphids and also mechanically. There is evidence that the two diseases may overlap in Missouri and Arkansas.

Cooperative research by State and Federal workers at Wooster, Ohio, established that the corn leaf aphid can transmit maize dwarf mosaic.

At Tifton, Ga., Dalbulus maidis, a known vector of corn stunt disease, was collected on volunteer corn from August 25 until the first killing frost on November 15, 1964.

Under greenhouse conditions at Tifton, 138 transmission tests were attempted using leafhoppers, other than D. maidis collected from corn growing in fields with plants displaying symptoms of corn stunt disease. Eighteen genera and 22 species of leafhoppers were represented. No symptoms of corn stunt disease were observed in any test.

In Mississippi 33 species of leafhoppers were collected on corn during the 1964 growing season. D. maidis was collected in large numbers during the period August 18 to November 19 in Louisiana, Texas, and Mississippi. Corn stunt virus transmission trials were conducted with 8 common species of indigenous leafhoppers. Discolorations which were not typical corn stunt virus symptoms developed on corn following feeding trials with Graminella nigrifrons, but no positive symptoms of corn stunt were observed.

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## POTATO INSECTS

Entomology Research Division, ARS

Problem. Control of insect pests is essential to the profitable production of high-quality potatoes demanded by the consumer. There is a continuing need for research to improve present control methods as insects develop resistance to insecticides and the public demands safer, more effective, and more economical methods of insect control. The overall problem is complicated in that many of the virus diseases of potatoes are transmitted by small populations of insects that otherwise would be of little importance. Sometimes it is not known which insects are responsible. It is important to learn the identity, distribution, and ecology of the vectors of diseases of potatoes in order to make an intelligent approach to the development of methods for preventing insect transmission of the diseases. There is an especial need for research on the ecology and biological control of potato insects; and for research on the evaluation of potato varieties for insect resistance. Growing concern over problems associated with insecticides which may also include adverse effects from residues in the soil, contamination of non-target areas, and interference with the work of natural enemies of insect and mite pests, makes it imperative that an increasingly strong research effort be directed to the development of non-chemical methods of insect control or of ways of using chemicals that will avoid objectionable side-chain effects.

### USDA AND COOPERATIVE PROGRAM

Basic studies on the biology, ecology, and pathology of insects that attack potatoes in the field or transmit virus diseases, as well as applied research on their control are conducted by the Department at Yakima, Wash., Orono, Me., Beltsville, Md., and Charleston, S. C., in cooperation with the respective State experiment stations, the Washington Department of Agriculture, the Washington State Potato Commission, and industry. In cooperation with the Crops Research Division studies on plant resistance were initiated at Ames, Iowa, under a grant to the Iowa State University of Science and Technology. Biological control studies at the University of Maine were initiated under a cooperative agreement.

The Federal scientific effort devoted to research in this area totals 4.4 professional man-years. Of this number 0.7 is devoted to basic biology; 1.5 to insecticidal and cultural control; 0.6 to insecticide residue determination; 0.6 to biological control; 0.2 to insect sterility, attractants, and other new approaches to control; 0.3 to evaluation of equipment for control and detection; 0.2 to insects that spread potato diseases; and 0.3 to program leadership.

In addition Federal support of research in this area under grants and cooperative agreements totals 1.2 man-years. Of this total 0.7 is devoted to biological control and 0.5 to plant resistance to insects.

A P.L. 480 Project in India on transmission of potato diseases by the green peach aphid was developed.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The State experiment stations have an effective potato insect research program under way.

The evaluation and integration of newly-developed chemicals with currently used insecticides, cultural methods, and pathogenic agents is being carried out. Information is being obtained on the influence of pesticide treatment on the development of natural enemy populations. Analyses of both tubers and soil are being performed to determine the amount of insecticide residue present following treatment and the rate of decomposition.

Studies are in progress to establish the relationship between insect-transmitted potato diseases and their vectors. The factors influencing these basic relationships are being analyzed and promising leads obtained are evaluated for their use in control.

Varietal crosses, selected seedlings, foreign varieties, Solanum species and interspecific hybrids are being evaluated for insect resistance. Resistant and susceptible strains are being studied to determine the nature of resistance mechanisms.

A total of 10.8 professional man years is devoted to potato insect research in the States.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAM

##### A. Basic Biology, Physiology and Nutrition

1. Aphids. Viviparous, summer forms of the green peach aphid, frequently overwinter in the Pacific Northwest on various winter-hardy plants in protected ecological niches. During the early spring of 1964 they were found overwintering at many locations in eastern Washington, northeastern Oregon and southeastern Idaho on shepherds-purse (Capsella bursa-pastoris), flixweed tansymustard (Sisymbrium sophia), running mallow (Malva rotundifolia), bouncing-bet (Saponaria officinalis), clasping-pepperweed (Lepidium perfoliatum) and tumblemustard (Sisymbrium altissimum). Following the severe winter of 1964-65 overwintering of the summer forms occurred at fewer locations and on fewer host plants but included hedge glorybind (Convolvulus sepium) not previously recognized as an overwintering host.

During winters in Washington when the green peach aphid is able to overwinter in both the egg and summer form stages, winged migrant forms are always produced earlier in the spring by the anholocyclic, or summer-form, than by the holocyclic form that overwinters in the egg stage. It was also found that whereas stone-fruit trees on which the holocyclic form lays its

eggs in the fall is not an overwintering reservoir for potato virus diseases, cull or stored potatoes used partly or wholly for overwintering some individuals of the holocyclic line may serve as an overwintering reservoir for some potato virus diseases.

Potato-infesting aphids were never abundant on potatoes at Presque Isle, Maine, in 1964. Fall and spring surveys indicated that the buckthorn aphid and the foxglove aphid would not be abundant but that the green peach aphid would be more abundant than usual, and the potato aphid of average abundance. Of several natural control factors, entomogenous fungi seemed most important. The action of predators on the primary host of the buckthorn aphid the preceding fall also was a strong contributory factor.

2. The Garden Symphylan. This pest severely damaged Russet Burbank potatoes in a field near Yakima, Wash., in 1964. Damage was spotty with some loads having as high as 35% culls. No damage occurred to the Norland variety planted in the same field.

3. The Six-Spotted Leafhopper. A 3-year study on the abundance of this insect on various host plants from May to September in Washington showed host preferences in the following order: Clover, carrots, winter wheat, fall barley, and potatoes. Maximum populations of adults were found in clover in July, carrots in August, winter wheat in July, fall barley in June, and potatoes in August.

4. Southern Potato Wireworm. At Charleston, S. C., 98% of the wireworm adults caught in light traps were of this species. A sample of 62 females examined in May and early June revealed that only 14% contained spermatophores indicating a very low percentage had mated. In cultivated land 141 adults were caught per trap per night in comparison with 0.08 per trap per night 100 feet within woodlands from May 28 to June 21. Wireworms taken from 19 fields were 93% southern potato wireworms.

#### B. Insecticidal and Cultural Control

1. Aphids. In field experiments in Washington five aphicides registered for use against the green peach aphid were applied as sprays to foliage with ground equipment. Satisfactory control was obtained with endosulfan 16 oz., endrin 9 oz., and demeton 8 oz. per acre but not with parathion 12 oz., or diazinon 8 oz. Di-Syston was the most effective material applied in sidedress applications of granules or concentrated water emulsions. Phorate and dimethoate were much less effective.

Following the mild winter of 1963-64, winged spring migrant forms of the green peach aphid were produced on both herbaceous and woody overwintering host plants throughout the potato growing area of eastern Washington. A survey of 30 commercial fields of Russet Burbank potatoes made in August and September showed that 5 applications of endosulfan kept the aphid at levels required to prevent damage from leaf roll carried by the insects.

In 4 fields receiving this treatment an average of only 2% of the harvested tubers contained net necrosis, an internal defect caused by the disease. Non-treated fields contained as much as 33% net necrosis.

In field experiments in Maine, foliage application of endrin, endosulfan, or phosphamidon and soil applications of Di-Syston in the seed furrow at planting time continued to give good control of aphids. The potato aphid continued to be more difficult to control than the green peach aphid, the buckthorn aphid, and the foxglove aphid. DDT applied weekly as a foliar spray was not only ineffective against these aphids but appeared to reduce the abundance of predators and parasites and thereby to increase the aphid populations. The use of insecticides in experimental plots did not affect total yield of Katahdin or Chippewa potatoes but tended to reduce the size of the tubers, especially in the Katahdin variety. Leaf roll readings made in 1964 of plants from tubers produced in 1963 showed the spread of leaf roll to be 6 to 25 times greater in untreated plots than in the treated. Little or no spread occurred in plantings treated with Di-Syston. In untreated plantings, the spread of leaf roll in Russet Burbanks was 1 to 4 times more than in Katahdins.

2. Spider Mites. A single application of 1 pound of phorate per acre in a spray was the most effective of 13 materials tested in Washington for control of the two-spotted spider mite on potatoes.

3. Wireworms. In field experiments in Washington, phorate was much superior to diazinon for control of the sugarbeet wireworm when applied as granules broadcast on the soil surface and worked into the soil before planting. Phorate, however, may leave residues in the tubers. Since there is no tolerance for this material in potatoes, this use cannot be recommended. In similar experiments, parathion was more effective than diazinon for control of the Great Basin wireworm, Ctenicera pruinina. Preliminary evaluations of several granular formulations of parathion showed that it is possible to stabilize, or hold, the insecticide so tightly in the granules that wireworms are killed too slowly, although some mortality occurs much later than would normally be expected.

The soil fumigant, 1,2-dibromo-3-chloropropane did not give satisfactory control of wireworms when applied as sidedress applications to potatoes at 4 pounds per acre.

### C. Insecticide Residue Determinations

1. Chlordane Penetration into Potato Pulp. In cooperative experiments at Presque Isle, Maine, with the Velsicol Corporation, it was revealed that although residues were much below tolerance, chlordane apparently penetrates and is deposited in cell walls of the potato tuber. From 0.09 to 0.12 ppm of chlordane was found in potato pulp, the residue of cell walls after the cells are crushed and the starch grains have been washed out with water in the starch-making process. From 0.09 to 0.11 ppm of chlordane were found

in Katahdin potato tubers grown in 1964 in soil treated at planting with chlordane at 4 to 8 lb/acre.

2. Organic Chlorine Insecticides. Chemical analysis in 1964 of Maine grown potato tubers showed that residues of insecticide were below the tolerance in tubers of Katahdin or Chippewa potatoes at harvest from plants growing in soil treated at planting with DDT at 10, aldrin at 2 or 4, chlordane at 4 or 8, or endrin at 1 pounds per acre. Also there were no measurable residues of endrin found in tubers from plants treated with two foliar sprays at 1/2 lb/acre.

In Washington the registered rate of 10 pounds of chlordane per acre applied broadcast and disked in the soil before planting potatoes in a field of sandy loam soil and a field of silt loam soil did not result in above-tolerance levels of residues in Russet Burbank potatoes but 20-pound rates resulted in nearly twice the established tolerance.

Samples of potatoes grown at Beltsville, Md., in soil treated with 10 pounds of DDT per acre and up to 8 pounds of chlordane per acre were analyzed for chlorinated hydrocarbon residues. The DDT and chlordane residues found were below the established tolerances of 1 and 0.3 ppm, respectively.

3. Organophosphorus Insecticide Residues in Potatoes. In field experiments in Washington, Di-Syston, schradan, and a mixture of the two were applied as granules in narrow bands at various depths in the soil before planting of potatoes. When Di-Syston was applied at 3 pounds per acre, residues of 0.16 and 0.07 ppm were found in potatoes where the applications were at the 3- to 6-inch and the 9- to 12-inch depths, respectively. No detectable residues were found in potatoes where the Di-Syston was applied at depths of 6 to 9 inches or 12 to 15 inches. Schradan at the same rate applied at all four levels resulted in residues in the potatoes with the larger amounts, 0.21 and 0.24 ppm, being found from the 9- to 12-inch and the 12- to 15-inch applications, respectively. The mixture of 2 pounds of Di-Syston and 1 pound of schradan also gave residues at all levels ranging from 0.21 to 0.48 ppm when calculated as Di-Syston and 0.12 to 0.26 ppm when calculated as schradan. The analytical method used did not distinguish between Di-Syston and schradan. In other experiments, granular and emulsifiable concentrate applications of dimethoate, Di-Syston, phorate, or schradan were made as a side dressing to potatoes a week after planting, either alone or in mixtures at the rate of 2.5 pounds per acre. Only dimethoate alone gave no residues in the harvested potatoes. The maximum residue found was 0.55 ppm calculated as Di-Syston.

Sidedress applications of parathion at 3 pounds per acre after the potato plants were up resulted in significant quantities of parathion residue in the harvested tubers indicating the need for a tolerance before parathion is used in this manner on commercial plantings. Parathion applied broadcast at the same rate and worked into the soil before planting continued to

leave no residues in the tubers.

4. Phorate and Zinophos in Soil. Phorate was applied to plots in Washington by broadcasting as granules at the rate of 3 pounds of active ingredient per acre and Zinophos (0,0-diethyl 0-2-pyrazinyl phosphorothioate) at the rate of 2 pounds per acre. Soil samples were analyzed at intervals from zero to 42 days after application of the insecticide. The phorate content was 1.38 ppm immediately after application and 0.21 ppm after 42 days; the corresponding Zinophos residues were 0.82 and less than 0.08 ppm.

#### D. Biological Control

Aphids. The number of aphid predators were greatly decreased in potato plantings at Presque Isle, Maine, in 1964, by spraying weekly with DDT. Two species of parasites, Trioxys carolinensis Smith and Aphelinus mali (Haldeman), not hitherto recorded from potato-infesting species of aphids in Maine, were reared from field-collected aphids.

General biology studies of a coccinellid aphid predator, Coccinella septempunctata, recently introduced from France, were begun at Presque Isle, Maine, in 1964. There is a possibility it can become established since, under identical conditions of hibernation in outdoor cages, it survived the winter as successfully as did the two most common species of ladybird beetles occurring locally. In another study, a very light dosage of the insecticide carbaryl proved highly toxic to the beetle. Affected beetles not killed outright by brief contact exposure on treated pepper foliage apparently never fully recovered. Egg deposition was greatly reduced following the required long period of recovery.

Important advances were made in techniques for rearing C. septempunctata utilizing closed glass or plastic jars containing a layer of excelsior to aid the larvae in avoiding each other. Either living aphids or quick-frozen aphids were satisfactory as food for the beetle larvae or adults. However, for the adult beetles the aphid diet was supplemented by feedings of a mixture of water, honey pollen and protein hydrolysate. About 1/2 man day was required to obtain 1,000 2nd instar larvae for release in field plots. One technician should be able to rear 8,000 to 10,000 per week with adequate aphids and equipment.

In small plot field experiments promising results were obtained with the distribution of predators for aphid control. Aphids did not become as abundant in plots in which eggs or larvae of C. septempunctata or eggs of Chrysopa spp. were put on the foliage of potato. Maximum control was 56 percent in these preliminary tests.

#### E. Insect Sterility, Attractants and Other New Approaches to Control

1. Preliminary tests indicated that adult Limonius spp. wireworms in Washington are attracted to yellow and orange objects.

F. Varietal Evaluation for Insect Control

1. Garden Symphytan. Preliminary observations in Washington indicated that this pest does not attack the tubers of the Norland variety of potato. Another red-skinned variety, LaSoda, and the Russet Burbank variety were susceptible to damage.
2. Six-Spotted Leafhopper. Bliss Triumph and Red Pontiac varieties of potato in Washington were less tolerant of the six-spotted leafhopper-transmitted aster yellows disease complex than Russet Burbank variety.

G. Insect Vectors of Diseases

1. Six-Spotted Leafhopper. A 3-year study of this insect as the vector of the mild, Washington strain of aster yellows on potatoes showed the disease to be of much less importance in Washington than leaf roll, transmitted by the green peach aphid. Although aster yellows caused many abnormalities in potato plants, such as yellow, red or purple colored leaves and stems, adventitious - or axillary - production of stems, spurs or aerial tubers and phyllody in the floral parts, the effect of the disease on potato tubers was not of great economic importance to growers of table stock crops. Tubers produced on infected plants either failed to sprout after winter storage, or if sprouting occurred, the sprouts were weak and produced spindling plants. This factor makes aster yellows a serious problem in seed-growing areas. Strangely enough, infected Russet Burbank potatoes remained hard and crisp during storage whereas infected Red Pontiac potatoes dehydrated rapidly, even prior to harvest, and soon became flabby and unsuitable as food. The area within the vascular ring of infected Russet Burbank potatoes was frequently gray in color although this off-color was not particularly objectionable to the consumer.

Although the six-spotted leafhopper overwinters in the egg stage in various grain and grasses the adults do not become abundant until July and August at which time most crops of potatoes are three-quarters grown. Late-season spread of aster yellows in central Washington probably prevents severe damage from this disease.

2. Aphids. A potentially serious virus disease situation in potatoes is developing in northeastern Maine. Leaf roll and potato virus-Y have gradually become more prevalent in seed stocks--especially in Russet Burbanks, the yearly acreages of which are continuing to increase. Since the advent of the use of planting-furrow application of granular systemic insecticides, seed-potato growers increasingly have discontinued the practice of removing the infected plants from their fields. Table-stock growers to not rogue their fields. In recent years the relative composition of the aphid population has gradually changed with an increasing proportion being the green peach aphid--the most important vector of leaf roll and of virus-Y. Systemic insecticides applied at planting time do not keep the potato plants sufficiently free of aphids towards the end of the season to

prevent late-season spread of leaf roll. A continuation of these trends could result in a repetition of the serious leaf roll situation that occurred in the late 1930s and early 1940s.

At Presque Isle, Maine, 49 percent protection from spread of leaf roll was obtained when viruliferous green peach aphids were placed in plots of Chippewa potatoes one week after the second of two weekly foliar applications of a 1/2-percent chlorocholine chloride-water mixture at 125 gallons per acre. This degree of protection is encouraging in view of the fact that the aphids were not removed from the plants prior to harvest some five weeks later. The mode of action of this chemical in preventing infection is not known. Absorption and translocation in the plant seems likely, since some protection from infection was experienced when the potato plants were sprayed with the mixture one week after being infested with the viruliferous aphids.

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## DECIDUOUS FRUIT, TREE NUT, GRAPE AND BERRY INSECTS

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Problem. Insects and mites are important limiting factors in production of high quality fruits, nuts, grapes, and berries, shortening the profitable life of the trees, vines, or plants, and reducing the yield or quality of the crop. Certain insects and mites transmit diseases that adversely affect the life and productivity of the host plant. No one method of control is fully satisfactory and methods that are effective now may not be so later. At present biological, cultural, and other non-chemical methods of control are only partially effective. Consequently, dependence must be placed on insecticides for control. The continued use of insecticides, however, is complicated by the occurrence of insecticide-resistant strains of an increasing number of insects and mites, by the need to avoid objectionable residues on fruits and berries and on their waste products used for livestock feed, by their detrimental effects on beneficial insects, fish, and wildlife, and by contamination of non-target areas. There is a continuing need for research to develop more selective, economical, and safer insecticides; and an urgent need, because of concern over the use of insecticides, for intensified research on alternative types of control such as those based on the use of attractants, repellents, traps, insect-resistant varieties and materials that affect insect growth and reproduction, including chemosterilants. More research is needed on integrated chemical-biological control programs with emphasis on less intensive insecticide usage, so that the maximum benefits from parasites, predators, and pathogens may be realized. Research is required to determine more fully the role of insects in the transmission of important diseases affecting the production of these crops, to discover the insect and mite vectors of the diseases and to determine their host preferences, distribution, and habits. Means must then be developed to reduce or eliminate the vector populations responsible for spread of the diseases.

### USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving entomologists, chemists, insect physiologists, and insect pathologists engaged in both basic studies and practical solution of growers' problems. Research on pome and stone fruit insects is carried on at Yakima and Wenatchee, Wash., Vincennes, Ind., Wooster, Ohio, Kearneysville, W. Va., and Fort Valley, Ga., in cooperation with the respective State Experiment Stations. Research on insects and mites affecting pecan production is carried on at Albany, Ga., and Shreveport, La.; on insects affecting the production of grape, blueberry and black walnut at Wooster, Ohio, in cooperation with the Ohio Experiment Station; and on strawberry insects at Beltsville, Md. Research on insects and mites in relation to the transmission of diseases of deciduous tree fruits is carried on at Riverside, Calif., Corvallis, Oreg., Wenatchee, Wash., and Fort Valley, Ga., in cooperation with the respective State experiment stations and the Crops Research Division. Work is also being

conducted under grants at the Washington, North Carolina, California, and Colorado Agricultural Experiment Stations, and at Brigham Young University in Utah.

The Federal scientific effort devoted to research in this area totals 21.6 professional man-years. Of this number 4.2 is devoted to basic biology and nutrition; 5.7 to insecticidal control; 2.1 to insecticide residue determinations; 0.5 to biological control; 4.6 to insect sterility, attractants, and other new approaches to control; 0.6 to evaluation of equipment for insect detection and control; 0.1 to varietal evaluation of resistance; 2.6 to insect vectors of plant virus diseases; and 1.2 to program leadership.

In addition Federal support under grants provides for a total of 3.7 professional man-years of research in this area. Of this total 2.1 is devoted to basic biology, physiology, and nutrition and 1.6 to insect sterility and attractants.

Additional research is in progress under grants of PL 480 funds (Projects E21-ENT-2 and 5) to the Institute of Pomology, Skierniewice, Poland, for studies of the differences in susceptibility and in cholinesterases in various species of spider mites as influenced by acaricides and for studies on the biological control of mites, aphids, and scale insects on deciduous tree fruits and effects of pesticides on natural enemies. Studies were also initiated by the Institute of Pomology, under PL 480 (Project E21-ENT-8) to study the mite fauna in Poland orchards with special reference to the relation between phytophagous and predaceous species. A portion of a grant of PL 480 funds (Project A17-ENT-5) to the Commonwealth Institute of Biological Control, Rawalpindi, Pakistan, for research on scale insects, fruit flies, and mites, and their natural enemies in West Pakistan is applicable to insects affecting deciduous tree fruits.

#### PROGRAM OF STATE EXPERIMENT STATIONS

A well rounded research program in this area is in progress in the States. Studies range from virus disease transmission by insects to the development of control measures involving comparisons of new insecticides. Integrated control measures are being developed in which the use of chemicals, cultural methods, natural enemies--in short, all factors which contribute to injurious insect control--are coordinated for maximum effectiveness. Schedules and new methods of application of pesticides are being evaluated to reduce residue levels and slow the development of pest resistance to these chemicals.

New techniques utilizing chemosterilants, repellents, and attractants are being investigated to determine their role in the maintenance of effective insect control programs. Light, bait, and mechanical traps are being evaluated as control methods and as means of detecting the abundance of insects regularly during the season. Information obtained in such surveys provides a basis for application of insecticide treatment only when necessary.

All feasible methods of insect control are based on the life history and behavior of pest species. Consequently, a large part of the research effort is concerned with fundamental studies. The influence of environmental factors such as temperature, host relationships, light, and other factors on development and mortality of several fruit insects are being investigated. In many instances, laboratory rearing of both pests and their natural enemies is being accomplished to accelerate the acquisition of biological information.

There are 62.5 professional man-years dedicated to research in this area in the States.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAM

##### A. Basic Biology, Physiology, and Nutrition

1. Codling Moth. The codling moth was reared continuously through 19 generations on a wheat germ diet at Yakima, Wash. Nineteenth generation moths were indistinguishable from those of the first generation; egg viability remained identical and fecundity was reduced only slightly. No abnormalities were apparent. Up to 97% of the larvae developed to the adult stage when reared individually in small plastic cups or glass vials of at least 1 inch in diameter. In smaller vials, larval webbing trapped and deformed the newly emerged adults. When two or three larvae were implanted per cup, the yields were 68.9% and 65.0%, respectively, but some cannibalism was observed. Some of the individuals exhibited retarded growth when they were not killed by other inhabitants of the same cup.

In a recent modification, trays 15 inches square and 4 inches deep were used for continuous rearing of large numbers of codling moths. The trays were filled to a depth of  $\frac{1}{2}$  inch with the rearing medium and 12 hours later eggs were surface-sterilized and implanted en masse on the surface. Egg viability was normal (80%) and 8 to 23% of the first instar larvae completed development. The remainder died without entering the medium. Current production with this method is about 200 moths per day. Methods are being investigated to reduce the larval mortality.

At Vincennes, Ind., the codling moth diet was mixed in large batches for the first time, then apportioned to small plastic cups, and infested with two newly-hatched codling moth larvae per cup. Of 9,800 larvae placed in the cups, 56% developed to the adult stage. Less than one percent of the cups was lost due to mold. Subsequent tests have shown that the use of three larvae per cup may result in at least a 10% increase in adult moth recovery. Pear wood was superior to creased-waxed paper liners in attractiveness as an oviposition substrate. Eggs averaged 52 per adult moth in cages containing pear wood compared with only 21 per adult in cages containing waxed-paper liners. The percent of egg hatch was 59% from pear wood and 53% from waxed-paper liners.

Dissection of female codling moths collected in bait traps at Yakima, Wash., showed that 7.2% were unmated, 56.3% had mated once, 15.5% twice, 8.3% three times, 5.9% four times, and 6.5% five or more times. The maximum number of matings observed was eleven. These data correspond with those in similar studies of females collected in light traps and are consistent with similar data obtained in previous years.

2. Peach Tree Borers. At Vincennes, Ind., larvae of the lesser peach tree borer were reared to adulthood on an artificial diet, consisting of the basic codling moth diet with alfalfa meal and peach wood shavings added. About 50% of the larvae reared on this diet developed to the adult stage. A few individuals of the peach tree borer and the American plum borer were also reared to adulthood on this diet. Last instar larvae of the lesser peach tree borer reared on artificial diet entered diapause. Exposure of the larvae to temperatures between 38 to 40° F. for 40 to 45 days were required to break diapause. The larvae subjected to this time and temperature requirement attained adulthood, mated, and deposited eggs. Recent studies have shown that rearing under continuous light conditions may prevent the borers from entering diapause. The lesser peach tree borer was also reared successfully on small thinning apples, approximately 1.25 inches in diameter. On this host the insects may be reared from egg to adulthood in a period of 40 to 45 days. The average length of head capsules of the lesser peach tree borer was 0.27, 0.45, 0.61, 1.02, 1.36, 1.76, and 2.30 mm, respectively, for instars one through seven. The average length of larvae was 1.20, 2.03, 4.09, 6.63, 11.36, 14.75, and 18.76 mm, respectively, for instars one through seven. Weight of larvae for instars three through seven was 0.0016, 0.0057, 0.0264, 0.0463, and 0.0809 gms. Eggs averaged 0.568 mm in length.

To provide peach tree borers for experimental studies at Fort Valley, Ga., cocoons were placed in sand-filled, screen-covered pans and kept moist. Emerging female moths were placed in cages where they mated with wild males they attracted. Mated females placed individually in 8-pound paper bags with cellophane windows deposited approximately 453 eggs each. Peach tree borer eggs hatched readily when bits of oviposition paper were pinned at the bases of 100 trees with the eggs next to the bark. However, only 1.5 borer adults per tree emerged the following year. When newly hatched larvae were placed on the trunks of peach trees, counts made the following spring indicated less than two surviving larvae per tree. Artificially infesting peach trees as a means of mass producing peach tree borers has not yet been successful.

At Fort Valley, Ga., newly hatched peach tree borer larvae grew vigorously on an artificial diet for 5 to 6 weeks after which growth was slow. Finely ground peach bark was then added to the diet and the larvae resumed active feeding. The larvae pupated but the cocoons molded and only one deformed female moth emerged. Less than 5% of newly hatched peach tree borer larvae, placed on small freshly cut peach roots in moistened vermiculite, emerged as adults. The emerging females were undersized but attracted males and deposited some fertile eggs.

3. Miscellaneous Insect Pests of Deciduous Fruit. At Fort Valley, Ga., peach trees representing commercial and home plantings in several counties as well as a planting on the station grounds were sampled for overwintering curculios. Samples from the station averaged 1.4 curculios per tree and those from home plantings, 0.7. In only one case were curculios taken from a commercial orchard, indicating their virtual absence where spray programs had been followed.

Modifications of the artificial diets used for rearing oriental fruit moth and melon fly were not successful in rearing experiments with the apple maggot at Wooster, Ohio.

4. Pecan and Other Nut Insects. Studies at Albany, Ga., on the effect of two miridae, Plaginothus repletus and Orthotylus ramus, on pecans indicated that the presence of these insects does not contribute to premature nut drop on the Stuart and Schley varieties of pecan.

Hickory shuckworm moths of the last summer generation oviposited readily when fed only distilled water in tests at Albany, Ga. Honey-water lengthened the life span and oviposition period but did not increase egg deposition. Although attempts to rear the hickory shuckworm on artificial media have not been successful, rearing on sprouting pecan nuts may be possible. When shuckworm eggs were placed on sprouting nuts they hatched, the larvae developed in the nut and adult moths emerged in 4 to 6 weeks. In one test 27 sprouted nuts infested with 135 eggs yielded 37 large moths when held at a temperature of 80° F. and 70% RH.

In other experiments at Albany, Ga., to determine the effect of refrigeration on diapausing hickory shuckworm larvae, 50% of the larvae emerged as adults after 26 days at temperatures of 33° to 38° F. The sexes were about equal in number. Fewer larvae reached adulthood when held at these temperatures for longer than 26 days and no moths emerged after 207 days.

Recent observations at Shreveport, La., indicate that the nut casebearer, obscure scale, phylloxera, black aphid, spittlebug, May beetles, shoot curculios, mites, a leaf miner, and possibly the fall webworm, are more prevalent in Louisiana than in Georgia.

5. Insect Vectors of Virus Diseases. Contrary to earlier indications, it was established at Riverside, Calif., that Eriophyes insidiosus, the peach mosaic vector, has a preference for ornamental, flowering varieties of peach. This knowledge will have usefulness in surveying for the vector mite in uninfected peach areas.

At Riverside, Calif., peach mosaic vector mite surveys resulted in the discovery of eight new species of eriophyid mites, all of which have been described.

Preliminary studies at Riverside, Calif., to develop methods of rearing pear psylla revealed that the appearance of summer and winter forms can be manipulated by regulating the photoperiod. When held in constant temperature cabinets, lighted at an intensity of 100 foot-candles, populations of psylla eggs and nymphs produced adults of the winter form when they received less than 14-hours' exposure to light per day.

At Corvallis, Oreg., Colladonus geminatus and C. montanus, leafhoppers which transmit western-X virus of peach and cherry, are under study to determine whether they are capable of transmitting little cherry virus. In diapause studies, C. montanus reared under 16-hour photoperiods laid eggs which hatched without delay; those reared under 8-hour photoperiods laid eggs but only a few hatched after six weeks. C. geminatus did not require specific photoperiod conditions for continuous development but were difficult to maintain, probably because of light conditions inadequate to produce suitable host plants for supporting their development.

#### B. Insecticidal and Cultural Control

1. Codling Moth. In laboratory screening tests against codling moth larvae at Yakima, Wash., Geigy GS-13005, Chipman RP-11783 and Niagara NIA-10242 were nearly as effective as the standard treatment of Guthion. Geigy GS-13005 and Shell Development SD-9129 were tested against codling moths in orchard plots and were as effective as the Guthion standard. However, Shell Development SD-9129 caused severe burning of apple leaves.

At Vincennes, Ind., Chipman RP-11783, Bayer 52553, and Upjohn U-20493, all at 4 ounces active material per 100 gallons, were 100% effective in preventing codling moth entries into thinning apples in the laboratory. Seven other compounds tested were of a lower order of effectiveness and not considered promising.

The effect of normal weathering of various insecticides on apples was determined by the field-laboratory bioassay method at Vincennes. Malathion (57 EC) plus American Cyanamid AC-52160 (4 lbs/gal EC), Guthion (25 WP), Niagara 10242 (50 WP), Geigy GS-13005 (40 WP), Shell SD-9129 (3.2 lbs/gal WS), carbaryl (50 WP), General Chemical 6506 (25 WP) were applied as cover sprays at 3 weekly intervals, beginning May 11. Four-hour-old deposits of all treatments were 100% effective against larvae of the codling moth. After 7 days of weathering, carbaryl, Guthion, and Shell SD-9129 had efficiencies of 99, 98, and 96%, respectively. After 14 days of weathering, Shell SD-9129's mean efficiency was 97%, and 73% after 21 days. The remaining compounds were much less effective at concentrations and intervals tested. There were no apparent significant differences in efficiency related to variety. Four-hour-old deposits of all treatments gave 100% mortality of adults after 24 hours exposure to treated foliage. Guthion and malathion plus AC-52160 were highly effective against the adult moths after 24 hours exposure to 7-day-old deposits while Geigy 13005, Niagara 10242, carbaryl, Shell SD-9129, and General Chemical 6506 were less effective. With the

possible exception of Guthion, none of the 14-day deposits gave significant adult mortalities.

At Kearneysville, W. Va., Chloropropylate and UC-19786 each gave good control of codling moth but were not equal to Guthion or carbaryl.

2. Orchard Mites. The following materials showed promise in laboratory screening tests against two-spotted spider mites at Yakima and Wenatchee, Wash.: Bayer 47416, 47940, 51295, 52553, and 54203; Geigy GS-12968, FL-342, and GS-13005; Chemagro 4671, 4738, and 4835; Commercial solvent P-252; Hercules 9326, 14503; Hooker HRS 1631; Monsanto 19203, 42320; Niagara 9241; Shell SD-9129; Spencer S-6900; Stauffer B-10228, N-3338, N-4372, N-5117, and R-8033; Thompson-Hayward TH-113-M; Thiocron; Upjohn 7175, GHS 146; U. S. Rubber BL-1310, BL-1311, BL-1315, DO 14; and Virginia-Carolina 3-665.

In orchard tests at Yakima, Wash., against mcdaniel mites, Union Carbide 19786 and 20047-A, Morestan, Bayer 37344, and binapacryl were effective. Binapacryl and Bayer 37344 were effective against European red mites.

Of 28 compounds screened at Vincennes, Ind., Hercules Powder 13843, Stauffer N-5117, Thompson-Hayward TH-113-M, Spencer Chemical S-6900-A3, and Chipman Chemical RP-11974 were promising enough to warrant further tests. Stauffer R-8033 and Velsicol OCS-21959 were not efficient foliar acaricides, but they showed considerable systemic activity.

At Vincennes, Ind., Morestan formulated as a dust or spray gave good control of European red mite, with no apparent difference between the two formulations. The compound caused mild phytotoxicity, but this was not considered a limiting factor. Binapacryl (50 WP), Morestan (25 WP), chlorobenzilate (25 WP), Chloropropylate (25 EC), tetradifon (12.5 EC), and Kelthane (18.5 WP) gave good control of orchard mites on 3 apple varieties when applied as 2 mid-summer treatments at weekly intervals.

At Kearneysville, W. Va., Morestan, Chloropropylate, and UC 19786 each gave outstanding control of European red mite in seasonal spray schedules. Each material markedly reduced hatch of mite eggs and maintained active mites at sub-economic levels.

In Poland (PL 480 project E21-ENT-5) Panonychus ulmi and Bryobia rubrioculus developed resistance to parathion and malathion sooner than to Meta-Systox-R and other systemic compounds under orchard conditions. This resistance pattern is similar to that which has occurred in the United States and in other countries.

3. Pecan Insects. In field trials at Albany, Ga., Guthion (25 WP) was superior to malathion (25 WP), parathion (15 WP), and EPN (25 WP) for black pecan aphid control. Malathion and parathion lost their effectiveness in 2 weeks, EPN in 4 weeks, but Guthion was still effective after 7 weeks.

EPN, Bayer 44646, Banol, and endosulfan were very effective against the pecan leaf casebearer. However, only the standard, EPN, was effective against the hickory shuckworm. In other field tests, 5 applications of the fungicides zineb and Du-Ter were comparable with 1 application of malathion for control of the pecan leaf casebearer.

Soil applications of Di-Syston granular at the rate of 3 pounds actual per acre were ineffective against the pecan leaf casebearer, the black pecan aphid, two yellow aphids, and Monellia sp.

4. Insect Vectors of Virus Diseases. At Riverside, Calif., application of diazinon in an experimental peach orchard at petal fall for control of the peach mosaic vector mite was continued for the fifth successive year. The spray program has virtually stopped spread of infection despite the presence of untreated diseased trees.

At Fort Valley, Ga., a spring application of 10, 30, or 50 grams of 10% granular Bayer 25141 to young peach trees controlled leafhopper vectors of phony peach virus disease and also gave 92, 94, and 97% respective reductions of terminals infested by oriental fruit moth larvae.

5. Miscellaneous Insect Pests of Deciduous Fruits, Nuts, and Berries. Application of 2% 60-viscosity oil on apples at the prepink stage failed to prevent a heavy infestation of San Jose scale from developing in Indiana. Application of 2% 70- and 100-viscosity oils at prepink and 2% 70-viscosity oil at the late dormant and pink periods gave substantial reduction in scale infestation.

At Vincennes, Ind., the effectiveness of insecticides after normal weathering was determined for the red-banded leafroller. As with the codling moth, four-hour-old deposits of all treatments were 100% effective against the larvae. After 7 days of weathering, the treatments gave the following average percent efficiencies: Guthion, 100; Geigy 13005, 100; carbaryl, 98; malathion + AC-52160, 97; Niagara 10242, 95; Shell SD-9129, 82; and General Chemical 6506, 67. After 14 days of weathering, malathion plus AC-52160 showed a mean efficiency of 91% and Guthion, 88%. The remainder of the treatments were much less efficient. After 21 days, malathion plus AC-52160 showed a mean efficiency of 77%; the remaining treatments were below 30%. Four-hour-old deposits gave 100% mortality of adults after 24-hour exposure to all treatments except General Chemical 6506, which gave 98%. After 7 days, Guthion, Niagara 10242, and malathion plus AC-52160 were effective adulticides but none of the compounds were effective after 14 days.

In laboratory screening tests at Wenatchee, Wash., Bayer 25141, 38156, 39197, 45556, and 47940; General Chemicals 9879, Hooker HRS 1667 and 1694; Hercules 9326; Naugatuck C912; Niagara 9241 and 10242; Shell Development SD-9129; and Stauffer N-3794 and R-8033, were effective against the green peach aphid.

At Fort Valley, Ga., Stauffer R-5092 and Imidan used at the rate of 1.5 pounds 50% wettable powder per 100 gallons of water gave 98 and 99% mortality of plum curculio, respectively, for 10 days after application. Effectiveness of both compounds declined rapidly during the succeeding 2 weeks. A single application of endrin at 2 pounds actual per 100 gallons as a post harvest trunk spray was highly effective in preventing peach tree borer infestation.

At Kearneysville, W. Va., Bayer 44646, Geigy 13005, and endosulfan effectively controlled lesser peach tree borer larvae.

At Wooster, Ohio, bait sprays of vegetable protein hydrolysates and malathion reduced apple maggot infestation in home garden orchards. Application with power equipment gave better control than when knapsack sprayers were used. Soil surface treatments with 10 pounds actual granular dieldrin per acre effectively reduced the number of emerging apple maggot and walnut husk fly adults. Tilling the dieldrin into the soil or increasing the dosage rate to 15 pounds per acre gave no increase in effectiveness. Fifteen percent of walnut husk flies emerging over a two-year period emerged the second year. Three applications of carbaryl plus malathion applied at 7-day intervals gave complete control of blueberry tip borer in blueberries. In studies to find powdery mildew fungicides that are compatible with carbaryl for grape insect control, folpet was the only effective material.

#### C. Insecticide Residue Determinations

Residues on or in fruit or foliage following insecticide applications were determined by chemists at Beltsville, Md., and Yakima, Wash. Washington pears sprayed with Guthion or Perthane 14 days before picking were divided into four lots. One was analyzed immediately, two kept in storage at 34° F. for 7 and 17 days, respectively, and the remaining lot held in storage for 7 days, then at room temperature for 24 hours and finally allowed to ripen at 75° F. and 60% humidity. The Guthion-treated lots contained 1.02, 0.93, 1.04, and 0.75 ppm, respectively, of Guthion. The Perthane-treated lots contained 1.66, 1.81, 2.01, and 2.01 ppm, respectively, of Perthane. In storage tests conducted the previous year, there had been a greater loss of insecticide during storage. In other tests, pears sprayed with Guthion wettable powder showed a residue of 1.38 ppm when picked 13 days later. Other mature pears sprayed with either a liquid concentrate or a wettable powder of Perthane had residues of 3.98 ppm and 0.90 ppm, respectively, 13 days after treatment.

Analysis of Indiana apples sprayed with binapacryl or Morestan showed that binapacryl residues declined to the minimum detectable level, 0.10 ppm, 21 days after treatment; the Morestan residues persisted in measurable quantities for at least 60 days after application.

Nut meats from Georgia pecan trees grown in soil treated with Di-Syston did not contain any detectable amount of this material at harvest time.

Samples of green Costa Rica coffee beans from trees grown in soil treated with Di-Syston or Bidrin showed no residues of either material above the

natural background of untreated coffee. Samples of Brazilian coffee treated with dieldrin contained 0.02 ppm of dieldrin in the hulls, but samples of depulped and dry pod coffee contained less than 0.01 ppm, the limit of sensitivity of the analytical method.

#### D. Biological Control

1. Aphids and Scale Insects. Coccinellid beetles were highly susceptible to standard dosages of nicotine sulfate and the organophosphates, Meta-Systox, "Intration," "Sayfos" (probably menazon), morphothion, and Folithion applied for control of Aphis pomi, in studies conducted in Poland (PL 480 project E21-ENT-2). Other predators, including anthocorids, syrphids, and cecidomyids, and the hymenopterous parasites Praon sp., Ephedrus sp., and Trioxys sp., were less severely affected. Reduced dosages of these compounds enhanced survival of all the predators and parasites studied, indicating the possibility of integrated control.

2. Orchard Mites. Studies in Poland (PL 480 project E21-ENT-8) showed that although high populations of the predaceous mite, Typhlodromus finlandicus, are present on apple foliage at the time of leaf drop, only about 10% survive until the following spring. Most of the mites fall to the ground with the leaves and fail to reach safe hibernating quarters under loose bark of the trunk or twigs. T. finlandicus was reared to adulthood in the laboratory on pollen or on the gall mite Aculus schlechtendali, but the adults did not oviposit. When held on clean leaves, the mites did not develop beyond the deutonymph stage.

3. Berry Insects. Small numbers of the predaceous mite Typhlodromus fallacis, present in Beltsville, Md., plots sprayed with aphicides in the fall of 1964 destroyed most Tetranychus telarius eggs as the latter were laid the following spring. By harvest time the number of fallacis mites varied from 0 to 7 per leaf while host mites averaged 0.1 per leaf on unsprayed plots. Acaricide-resistant telarius mites from experimental plots, receiving an intensive aphicide spray program, failed to build up in the unsprayed plots because of fallacis mites, suggesting that spider mites on strawberry plantings increase in importance when predator mites are destroyed by aphicides. Introductions of the predaceous mite Phytoseiulus persimilis at the rate of 200 per 10 feet of row failed to become established on strawberry plots heavily infested with spider mites.

#### E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Codling Moth. Moths sterilized with tepa and then released into an isolated apple orchard in 1965 in Washington were very active and were caught in large numbers in bait traps, light traps, and sex attractant traps. In sexual aggressiveness tests conducted in the laboratory, female moths caged without males lived 9 days but only 6 days when caged with male moths at a 1:1 ratio. As the ratio of male to female moths increased, the female longevity decreased. Female longevity was also positively correlated

with increasing dosage of the sterilizing treatment the males had received. The longevity of females caged at a ratio of 3 untreated males to 1 female was 5 days; with males treated with 40 kr of radiation or 15 ug tepa, 6 days; and 30 ug tepa, 9 days. In preliminary tests to develop methods of mass treatment with chemosterilants, male moths were attracted through a glass tube in which the inner wall was treated with tepa. When males treated in this manner were mated with untreated virgin female moths, reductions in egg hatch were consistent with changes in the dosage used. The sequence in which normal female codling moths were mated with normal and sterile males affected the percent egg hatch. When females mated first with normal males, then with sterile males, 13% of the eggs hatched; but when mated first with sterile males and then with fertile males, egg hatch was 41%.

At Wenatchee, Wash., the antibiotics actinomycin D, cytovirin, hygromycin B, sheptovitacin A, cytovirin and amphotericin A reduced codling moth oviposition.

Codling moth sex attractant was extracted from female moths with various solvents at Yakima, Wash. The attractant was also collected from air passing over female moths or by washing glass surfaces on which female moths had rested. A plastic cage used to contain live female moths remained attractive to male moths for 6 days after the females were removed. In laboratory bioassays, the males became more responsive to attractants as the purity of the latter increased. The same was true in orchard tests when the attractants were placed in the orchard during the flight period at about 9:00 pm. When extracts were placed in the orchard at mid-day, crude extracts of complete moths were most attractive, followed by crude extracts of the tips. More purified extracts did not attract moths, probably because they had volatilized before the moth flight. In field cages traps containing 5 live virgin females each caught 3 times as many male moths as traps containing extracts of 50 virgin females each. In orchard tests the live-female traps caught 8 times more males than did the traps containing extracts. Live-female traps also caught many more moths and at an earlier date than did light traps or bait traps. Field cage tests indicated a large variation in the attractiveness to males by individual females.

Nine previously screened candidate insect attractants, supplied by Pesticide Chemicals Research Branch, were retested at Vincennes, Ind., as codling moth adult attractants. Of these, 3 showed promise in olfactometer tests.

2. Lesser Peach Tree Borer. At Vincennes, Ind., 10.3 cords of infested peach wood yielded a total of 4,427 adults, which emerged from May 6 through June 30, 1965. Of the total, 47.6% were females. The moths were used in attractant studies. In 1964, live virgin female traps were utilized to attract male lesser peach tree borers in a block of 235 peach trees, located approximately one mile from the nearest peach orchard. Indications were that males were attracted, not only from the block in which the females were placed, but also from surrounding orchards. In a continuation of the

study in 1965, a total of 579 males were taken during May and June from five trap locations within the test block. In 10 traps placed around the periphery of the test block at distances of  $\frac{1}{2}$  to 1 mile away, captures totaled 873 males during the same period.

3. Miscellaneous Insect Pests of Deciduous Fruits and Nuts. At Vincennes, Ind., extracts secured by washing red banded leafroller females with either methylene chloride or ethyl alcohol, or by macerating whole female insect bodies in either of these solvents, elicited strong mating responses from the males when presented with dried residues of these extracts. The methylene chloride wash elicited the strongest response, followed by the macerates in methylene chloride and ethyl alcohol. In olfactometer tests, twice as many male moths were recovered from the sex pheromone source as from the blank source, and methylene chloride extracts were far superior to the alcohol extracts.

Tepa, apholate, tretamine, ENT 50173 and ENT 50611 reduced oviposition by pear psylla in tests at Wenatchee, Wash. Pactomycin, Ampicillin trihydrate, 2-thiouracil, and apholate caused reduced oviposition by the green peach aphid.

At Albany, Ga., 2% apholate sprayed on hickory shuckworm moths effectively sterilized males and females, without increasing mortality over untreated moths.

A mixture of vegetable protein hydrolysate, dibasic ammonium phosphate and benzoate of soda in water was superior to 14 other mixtures in attracting apple maggot adults to sticky board traps at Wooster, Ohio. Deadline, Stikem, and Tanglefoot were equally effective as the sticky material used on the sticky board type traps. Walnut husk fly adults were attracted in about equal numbers to the same protein hydrolysate mixture that attracted apple maggots, and to straight 28% aqua ammonia.

#### F. Evaluation of Equipment for Insect Detection and Control

1. Pecan Insect Control Equipment. In tests at Shreveport, La., aerial applications of parathion and malathion were erratic in controlling the black pecan aphid and the mite, Eotetranychus hicoriae. Kelthane (18.5% WP) at 2 pounds or chlorobenzilate (50 E or 4 lb/gal) at one pint per 100 gallons of water, applied as standard dilute sprays with an air blast sprayer, gave effective control of the mite. Sampling of a pecan orchard for pecan nut casebearer infestation, following the aerial application of 10 pounds of parathion 15% WP plus 5 pounds 50% DDT WP, in 20 gallons of water per acre, showed an infestation of 4% in the treated block and 37% in an adjacent untreated block.

## G. Insect Vectors of Diseases

1. Pear Decline. At Riverside, Calif., vector tests with pear psylla added a significant number of apparent pear decline transmissions from affected field trees to potted pear trees, plus transmissions from the reacting potted trees to new healthy potted trees. Parallel feeding tests in which pear psylla had not been allowed to feed on decline-affected trees before being caged on potted trees showed that the test trees could be killed or caused to decline markedly only by extremely dense populations of the insect. The additional evidence for the viral-cause hypothesis for pear decline was the result of an improved virus indexing technique. When potted trees in which decline symptoms had appeared following exposure to pear psylla in vector tests were joined by approach grafts to healthy trees, with all insects eliminated, the healthy trees reacted promptly with decline symptoms. Healthy trees similarly joined to other healthy trees elicited no reaction. The approach-graft technique came after bud implantations from diseased trees into healthy produced few transmissions or reactions within a 1- to 3-year period of observation.

2. Miscellaneous Stone Fruit Virus Diseases. A new, as yet unnamed, damaging, rapidly spreading virus of cherry was readily transmitted by several species of aphids at Corvallis, Oreg., a unique situation with woody-plant viruses. Aphids incriminated as vectors were Myzus cerasi, Aphis pomi, Acyrtosiphon pisum, Myzus lythri, Macrosiphum rosae, Myzus persicae, and Aphis craccivora. The green peach aphid, Myzus persicae, was found to transmit the virus only during the first hour after removal from infected plants.

At Fort Valley, Ga., Oncometopia nigricans was confirmed as a vector of phony peach disease in 1962. Two more trees inoculated by viruliferous O. nigricans adults in 1961 were confirmed as being infected in the spring of 1965 when transverse root sections gave positive reactions to the acidulated methanol test.

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## CITRUS AND SUBTROPICAL FRUIT INSECTS

Entomology Research Division, ARS

Problem. Insects and mites that attack citrus and subtropical fruits reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase cost of production. There is a continuing need for research to secure biological and ecological information on these pests that will provide a better basis for the development and implementation of insect control methods than that now available, or suggest additional non-chemical approaches to their control. Additional research is needed on biological control agents, including parasites, predators, and pathogens and on methods for more effectively integrating biological, chemical, and other control measures. Safer, even more effective and economical control procedures that will minimize or avoid objectionable chemical residues and problems associated with residues should be developed. The research on attractants, chemosterilants, sterilization techniques, and genetic methods need increased attention. Protection against introduction into the United States of tropical fruit flies or other foreign injurious insect species requires research to provide effective low-cost detection methods, processes for destroying insect infestation in fresh fruits and vegetables intended for shipment to uninfested areas and eradication procedures for use in emergency situations to eliminate incipient insect infestations.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving both basic and applied research on insects and mites infesting citrus and subtropical fruits and on treatments for control of insects and related pests in commodities regulated by plant quarantines. This program is carried on at Beltsville, Md., Honolulu and Hilo, Hawaii, Riverside, Calif., Orlando, Fla., and Brownsville and Weslaco, Tex., in cooperation with entomologists, chemists, and agronomists of the respective State Experiment Stations; also at Orlando, Fla., in cooperation with the Crops Research and Plant Pest Control Divisions; at Hoboken, N.J., in cooperation with the Plant Quarantine Division; at Mexico City, Mex., in cooperation with the Plant Pest Control Division and with the Direccion General de Sanidad Vegetal of the Mexican Secretaria de Agricultura y Ganaderia and on the islands of Guam and Rota in cooperation with the Territory of Guam, U. S. Navy, and the Trust Territory of the Pacific Islands. Work was initiated in 1964 in San Jose, Costa Rica, on the Mediterranean fruit fly with funds supplied by the Agency for International Development (AID) in cooperation with the Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA) and with the Interamerican Institute for Agricultural Sciences at Turrialba, Costa Rica. Research formerly conducted in cooperation with the Florida Agricultural Experiment Station at Lake Alfred was transferred to the Orlando, Fla., and Weslaco, Tex., laboratories in January 1965.

The Federal scientific effort devoted to research in this area totals 29.3 professional man-years. Of this number, 7.3 is devoted to basic biology, physiology, and nutrition; 2.7 to insecticidal control; 1.1 to insecticide residue determination; 2.3 to biological control; 10.0 to insect sterility, attractants, and other new approaches to control; 4.0 to insect control treatments for commodities regulated by plant quarantines; 0.1 to varietal evaluation of insect resistance; 0.5 to insect vectors of diseases; and 1.3 to program leadership.

PL 480 research grants include India (A7-ENT-26) Biology of gall midges affecting mangoes with special reference to extent of damage; India (A7-ENT-35) Biology of gall midges affecting citrus plants with special reference to the extent of damage; Pakistan (A7-ENT-5) Studies on scale insects, fruit flies, and mites and their natural enemies in West Pakistan; Greece (E11-ENT-1) Control of the olive fly with radiation or chemical sterilization procedures; Egypt (F4-ENT-3) Induced sterility in males of Mediterranean fruit fly as a means of controlling and eradicating that pest.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The States are engaged in both basic and applied research on citrus and other subtropical fruit insects. Attempts to establish more effective complexes of biological control agents have led to the importation of new natural enemies from other areas of the world, the most promising of which are being reared in quantity and colonized in the field. The influences of adverse factors on native and imported biological control agents is being determined by correlation of field population counts with weather cycles and pest control treatments and by laboratory studies of temperature, humidity and other factors.

Injurious species are being studied to ascertain the type and extent of damage produced by each, methods of predicting outbreaks, mass rearing methods, seasonal population fluctuations and other biological information upon which integrated control measures may be based.

New insecticides are being evaluated to determine the most effective methods of application, dosages, compatibility with other materials, phytotoxicity, effect on beneficial insects, safety of application and residue levels on and in fruit. Particular attention is being devoted to spray oils because of the safety of their use and the fact that no evidence of resistance has appeared in any of the insect pests for which they are being used.

New techniques for sterilization of citrus and avocado fruits against fruit flies are being evaluated, so that the produce may be moved from quarantine areas into uninfested areas without containing harmful residues.

The total State scientific effort concerned with citrus and subtropical fruit insects is 19.7 professional man years.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Citrus Insects and Mites. Brown soft scale in citrus plantings in Texas failed to increase during May and June as in previous years. Infestations were at their lowest seasonal level since 1962 when a severe freeze caused extensive damage to citrus trees and reduced scale populations. In June 1965 scale counts averaged only 0.005 scale per leaf. In June of 1964 mean infestation was 1.9 per leaf. Parasitism was low in both years suggesting that factors other than parasites may have been responsible for the 1965 decrease. In past years heavy scale infestations followed soon after the start of cotton spraying on a 4- to 7-day application schedule. Drift from methyl parathion has been suspected as a factor contributing to the brown soft scale problem. One explanation for failure of brown soft scale infestation to increase as expected may be the possibility of less drift because of extensive use of low-volume formulations.

At Hargill, Tex., a 380-acre orange grove was sprayed by plane on May 2 with 2 pounds active methyl parathion per acre. On June 21 brown soft scale infestations averaged about 2 scales per leaf. The highest infestation in 21 Lower Rio Grande groves surveyed in June was 0.04. An additional methyl parathion spray to a portion of the Hargill grove caused the scale population to increase 250% in two weeks, while in a portion of the same grove not sprayed the second time, the increase was only 24%.

In a cooperative study with the Soil and Water Conservation Research Laboratory at Weslaco, infra-red aerial photography showed promise as a quick and effective method to determine presence of heavy scale infestation on citrus in large area plantings. Observations in groves verified that individual trees with heavy scale infestations could be identified with aerial photographic techniques.

In dispersal studies of the citrus red mite at Riverside, Calif., on orange trees in the field, the adult female was the predominant dispersal stage, representing 80% of all motile forms recovered. Sixty-three percent of the total mites recovered had moved upward, 22% horizontally, and 15% downward from points of release. At a mean temperature of approximately 70° F maximum known dispersal was 8 feet in 2.5 weeks; at 50° F it was 3 feet for the same period. One hour after simultaneous release of both albino and red strains on lemon shoots with little foliage to impede movement, 4 and 3% of the total red and albino mites, respectively, were recovered ~~between~~ 3 - 4 feet above the points of release.

Plastic, paraffin, animal membrane, cellophane, and vegetable cellulose films were tested at Riverside, Calif., to develop procedures for rearing the citrus red mite on artificial media. Only cellulose films provided a satisfactory surface on which the mites would remain and feed. Albino mites of all stages were placed on membranes and examined for feeding on 10%

sucrose solution containing red food dye. Immature forms fed through thin paraffin or cellulose as shown by the presence of the dye in the mites. Millipore® filters adhering to vegetable parchment provided the most satisfactory surface. All mites including newly hatched larvae, fed through this membrane and many molted successfully with some immatures developing to adults.

Life span of male California red scales at Riverside, ranged from 2 to 60 hours, with a half life of approximately 6 hours. Individual males introduced into cages of virgin females fertilized an average of 15 females with a range of 0 to 30. Under artificial illumination, mating occurred during the entire 24-hour day. Females became attractive to males shortly after the start of the gray adult stage and remained attractive as long as they were unfertilized. Within 24 hours after fertilization the pygidium was retracted and the female no longer elicited male response. Multiple matings with 2, 4, and 8 different males did not increase the biotic potential of individual females.

In Florida differences in susceptibility to feeding on citrus seedlings by citrus bud mites (Aceria sheldoni) was demonstrated in the laboratory. Florida sweet seedling, Key lime, and Duncan grapefruit exhibited feeding damage after 3 weeks. After 7 weeks, these varieties, plus pineapple, Cleopatra, Temple, and Murcott showed symptoms of severe bud mite injury, consisting of shortening of internodes, multiple bud growth, witches-broom, and leaf cupping. Troyer, Trifoliata and Carrizo had no damage symptoms until 21 weeks after infestation.

2. Subtropical Fruit Flies. Olfactometer tests in Hawaii revealed that a sex pheromone may be produced in the male and not the female oriental fruit fly. Sexually mature, unmated, normal oriental fruit fly females had a strong short-range attraction to males against a 2 mph airflow. In Hawaii, male oriental fruit flies irradiated as pupae lived the same length of time as normal laboratory-reared flies, but the normal female flies died at a greater rate than irradiated females. After 6 weeks the surviving male/female ratios were 3.4/1 for normal flies compared to 0.94/1 for irradiated.

In Hawaii about 15% of (picked) ripe coffee cherries were found infested by the Mediterranean fruit fly. Fruit from coffee trees encased in fiber glass screen cages with or without flies was harvested and graded 10 times in the 6-month producing season. The percent by weight of cherry coffee in No. 1 grade ranged from 14 to 67 from infested trees and 89 to 100 in the uninfested. Much more unrecoverable loss by dropping was associated with infested cherries. Defects included fruit with withered or hardened skin, decayed pulp, moldy pulp, and less than 1.0 specific gravity. Formerly the berries were harvested before those infested dropped or developed defects, but higher labor costs now prevent frequent picking. Possible adverse effects on taste and size of bean require further study.

Oriental fruit fly attack on ripening papaya under controlled conditions in Hawaii produced a positive correlation between infestation and Rhizopus infection, the disease incidence being increased 10X. Anthracnose was cultured from the bodies of 15% of field-collected flies and parasites, suggesting that under favorable conditions the insects may be involved in the spread of this disease.

In Mexico three male Mexican fruit flies were recaptured 9 to 11 months after release. One male was recaptured in the same grove in which it was released and the other two in a grove located approximately two miles away from the release point.

In mass rearing the Mediterranean fruit fly at San Jose, Costa Rica, addition of 0.1% each of tegocept and sodium benzoate to the larval rearing medium effectively controlled severe fungus contamination which had sharply curtailed the rearing program. During the period January to March 1965, a total of 33,245,120 pupae were recovered from 156,360,000 eggs for a mean yield of about 21%.

A method was devised for automatically marking flies for sterile male releases by allowing them to contact a fluorescent powder with their ptilinum as they emerge from the puparia. The powder, which is non-water-or alcohol-soluble, fluoresces readily under ultraviolet radiation after the ptilinum has been retracted into the head.

The number of pupae placed in the release stations, which consist of fiber cotton containers measuring 43 cm in diameter and 35 cm in height, was found to be the major factor responsible for excessive mortality of sterile Medflies released at Puntarenas. Post-emergence adult mortality increased more than 6-fold when the number of pupae per station was increased from 25,000 to either 50,000 or 80,000. The mortality at the higher pupal concentrations was the result of injury brought about by overcrowding and competition for the available resting surfaces required by newly emerged adults. Prevailing ambient and within station temperatures were investigated and eliminated as a factor contributing to the mortality problem. In recent tests, insertion of dried tropical almond leaves in the release stations to provide additional resting surface for the newly emerged flies reduced the mortality from 50 to 4%, even where 50,000 pupae per station were employed.

Research in Greece under PL 480 Project E11-ENT-1 showed that gamma ray doses of 6, 8, 10, and 12 kilorad, applied to the advanced pupal stage of the olive fruit fly (Dacus oleae), effectively sterilized the adult males without affecting their longevity. These doses also caused permanent sterility in the females.

In Egypt under PL 480 Project F4-ENT-3 outstanding progress was made during the past year in developing a technique for mass rearing the Mediterranean fruit fly. An earlier problem of contamination of the larval rearing medium with phorid flies was resolved by rigid sanitation procedures. Production

of up to 400,000 Medfly eggs per day has been demonstrated with present rearing techniques.

3. Southern Green Stink Bug. In Hawaii improved methods were developed for mass producing the southern green stink bug that provide a 25X population increase per generation (5 weeks) at a cost of approximately 5 man hours labor and \$1.75 for food per 1,000 adults. The best nymphal diet consisted of soaked and waxed raw seeds of garbanzo and peanut. The bugs were found to have gregarious feeding habits before each molt. Special manipulation and cage design were necessary to take advantage of this habit. Crumpled paper towels provided ample resting space before the final molt. Water had to be provided when dry or soaked seeds were fed but not when succulent materials (cabbage, green beans, fresh corn, etc.) were supplied. Wild bugs deposited twice as many eggs (100 per female) as laboratory reared bugs.

#### B. Insecticidal Control

1. Citrus Insects and Mites. In the laboratory screening program of new chemicals against California red scale at Riverside, Calif., 2 compounds with lower mammalian toxicity than parathion were as effective as parathion in initial toxicity and residual activity. These were Stauffer N-4446 and R-5763.

In field evaluation studies at Orlando, Fla., GC 9160 gave almost complete control of citrus rust mites for 3 months but was ineffective against Texas citrus mites (Eutetranychus banksi). Stauffer N-4543, ethion plus oil, and Pentac were the most effective materials for control of Texas citrus mites. GC 9160 and chlorobenzilate failed to control Texas mites, while zineb caused a marked increase in Texas mites.

#### C. Insecticide Residue Determinations

1. Citrus Insects and Mites. Drift of methyl parathion into Texas citrus groves from airplane sprays was determined by analysis of deposits on foliage and on filter paper on horizontal stands at various distances in the grove downwind from line of flight. Methyl parathion was applied at the rate of 0.5 lb. actual insecticide per acre and determined following 10 plane passes along a single line of flight. Deposits of methyl parathion on leaves ranged from 4.42 ppm at a distance of 110 feet downwind to 0.2 ppm at 1380 feet downwind. Deposits on filter paper ranged from 277 micrograms per square foot at 110 feet to 3.6 per square foot at 1380 feet.

Bioassay measurements of drift conducted with parasites and predators in screen-cages showed complete kill of Aphytis proclia, a chaff scale parasite, 400 feet downwind from the spray source and 77% mortality at 1380 feet. Lacewing adults were unaffected when exposed in the same manner but were killed when exposed to methyl parathion deposits on citrus terminals.

Drift of low-volume and high-volume application of malathion by airplane was compared in Texas. From 2 to 3 times as much technical as dilute material was deposited directly below the flight line, but drift from both formulations was recorded at 1400 feet downwind - the maximum distance tested. It was shown that 2.4 times more malathion from technical formulations than from the dilute came down in sampling stations within a 1400 foot test area. This may indicate that more spray from the dilute formulation was broken up into very fine particles that could have been carried aloft and drifted beyond the test site. In bioassay tests with Aphytis proclia, drift from both formulations caused complete kill 500 feet downwind.

#### D. Biological Control

1. Citrus Insects and Mites. Eleven species of parasites and 2 hyper parasites have been reared from brown soft scale collected in lower Rio Grande Valley groves. Of these, the following are new Valley records: Encyrtus infelix (Emb.), Aphycus pulvinariae How., Encyrtus bicolor (How.), Anicetus annulatus Timb., Microterys flavus (How.), and a Pseudaphycus sp., Coccophagus lycimnia comprised over 90% of adult parasites reared from scales collected in valley groves.

Sampling of groves exposed to insecticide drift from nearby cotton plantings show fewer coccinellids and lacewings on trees closest to cotton, indicating that they may be affected by drift.

Field studies with caged citrus trees showed outstanding control of brown soft scale by coccinellids. Scale counts on 5 1-foot grapefruit terminals showed that 500 adult Chilocorus cacti (L.) had reduced scale 95% between July and December, from 9607 to 448. In counts on a tree caged with 1000 adults of the dominant brown soft scale parasite, C. lycimnia increased 438% from 430 to 18,858. In counts on a caged check tree scales increased 1081% and, before the final count, the tree was killed by scale. On an uncaged check tree, scale decreased 77% from 9909 to 2309. Parasitism on this tree reached 23.5%, which was from 3 to 6 times greater than on any of the trees under test. Predators entering the grove probably helped in the natural reduction of scale on the uncaged tree. If parasites had been responsible for the scale decrease on the uncaged tree, then parasite populations in the grove must have eventually exceeded 1000 per tree. This number released on one of the caged trees failed to control scale and permitted a 438% increase.

At Riverside healthy citrus red mites lived 2 to 3 times longer and laid 6 to 30 times as many eggs as mites infected with a virus diseases. The albino and normal red strains of mites reacted similarly to the disease. Within 24 to 48 hours following spraying with a virus suspension, inoculated mites were able to transmit the virus to healthy mites. Transmission continued as long as inoculated mites were alive. Transmission also occurred in cases where inoculated mites produced no birefringent crystals, further indicating that not all infected mites produce crystals.

Citrus red mites were infected with the virus disease by feeding through inert polyethylene membrane on suspensions of triturated diseased mites in 10% sucrose solution for 2, 6, or 24 hours. Mites were allowed to feed for 6 hours through the membrane on dilutions of the virus ranging from 1 mg of triturated diseased mites per 1 ml of 10% sucrose solution to 1 mg to 1000 ml. There was a gradual decline in infection from 50% with a 1:1 dilution to 11% with a 1:1000 dilution.

Populations of citrus red mite increased to economic levels when application of the virus suspension by sprays or introduction of inoculated mites into 3 field plots at or near Riverside, Calif., were suspended. A single re-treatment resulted in reduction of the population to subeconomic levels.

Healthy and virus-inoculated albino mites released simultaneously in adjacent navel orange trees at Riverside, dispersed up to 5 feet in 2 days for healthy mites and 6 feet in 4 days for virus inoculated mites.

During a field epizootic of the virus disease of the citrus red mite in a 12.5 acre lemon grove near Riverside, Calif., the initial mean population of 68 eggs, 35 immatures, and 6 adults per leaf in January 1965 gradually diminished to a mean of less than 1 immature motile form per leaf and 1 adult per 5 leaves in June. The incidence of disease, determined by crystal-liferous live and dead mites, has ranged from 47% to 4%. Subeconomic mite levels have been maintained since mid-March.

Field experiments conducted at Orlando, Fla., again showed that zineb caused a buildup of Texas citrus mites. A positive correlation was shown to exist between zineb applications, decrease of Entomophthora sp., a fungus parasite of Texas citrus mites, and the increase in mite population. Reduction of Texas mites was obtained by fogging trees with water. The moisture apparently assisted the fungus parasite in becoming established.

An Entomophthora sp. fungus, parasitic in Texas citrus mite was found to have a 5- to 6-day life cycle under laboratory conditions at Lake Alfred, Fla. Death of mites occurred 4 to 5 days after infection. This fungus is prevalent in many groves and is believed to contribute materially to natural control of this mite.

Studies were continued under PL 480 Project A17-ENT-5 to determine the natural enemies of scale insects, fruit flies, and mites in West Pakistan. In 9 species of scale insects collected from a variety of plants, parasitism was moderately high, even in low density infestations. Parasitism of the California red scale was about 17%, the yellow scale 16%, and the olive scale 14%. An infestation of from 17 to 22 Tecaspis sp. scales per leaf on olive was controlled mainly by the lady beetle, Chilocorus infernalis, in August. Several new species of Anthocoridae were found predaceous on phytophagous mites.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Citrus Insects and Mites. Studies of the nature of a sex pheromone in the California red scale at Riverside, Calif., showed that males were attracted to exudates of crushed females on filter paper and females unattractive in situ became attractive when crushed. Crude extracts of whole virgin females crushed in numerous solvents were attractive to males. The solvents resulting in the most attractive extracts in descending order of male response were diethyl ether, acetone, chloroform, hexane, and methylene chloride. Attractiveness to the males was enhanced by exposing the extract on dummy females modeled with paraffin drops. In another method of extracting the sex pheromone, air drawn through an air-tight box containing approximately 10,000 virgin females on lemons into a cold trap, produced 325 ml of liquid in 20 days. This was extracted by mixing with diethyl ether and the ether reduced in vacuo at low temperature to 20 ml. Two- $\mu$ l aliquots of this concentrate placed on dummy females were as attractive to males as similar amounts of diethyl ether extracts of 50 crushed females.

2. Subtropical Fruit Flies. Aerial releases of sterile oriental fruit flies at the rate of about 1 million per week for 10 months in the 42-square mile area of Tinian and Aguijan in the Mariana Islands nearly eradicated the species there, but a persistent infestation of wild flies in high interior valleys on Saipan provided a source for reinfesting Tinian and surrounding areas on Saipan. During the same period, releases on Saipan (48 sq. mi.), at the rate of 2.5 to 3.5 million flies per week from 50 ground sites only, did not give adequate overflooding. Longevity of ground released flies was greatly reduced.

In late January the Hawaii station initiated a male annihilation program on Saipan, Tinian, and Aguijan (90 sq. mi.) to replace the sterile fly releases at a time when wild male oriental fruit fly catches were averaging about 100 flies/1000 trap days. A methyl eugenol-solution containing 3% naled (by volume) was used to saturate cane-fiber board squares 1"x1"x $\frac{1}{2}$ " (later increased to 1 $\frac{1}{2}$ "x1 $\frac{1}{2}$ "x $\frac{1}{2}$ "). Each square held from 5 to 15 grams of the lure, depending on size and composition of board. The squares were distributed at uniform intervals along flight lines (from 500 to 3500 ft. elevation depending on weather) 1/5 mile apart at a mean speed of 150 mph. In towns, similar squares were distributed by jeep. Applications were made at approximately 2-week intervals until 10 full and 2 partial applications had been made to Saipan and 8 to the other islands. Traps showed a substantial decline in fly catches with each generation. In the first month catches decreased to 50 flies per 1000 trap days. Catches of three successive generations declined to 7.4, 0.7, and 0.4 per 1000 trap days respectively. Since then none was caught. During the last two generations in April and May, a heavy crop of mangoes ripened and other preferred hosts were abundant. Despite favorable conditions no flies could be found on the extreme northern Mariana Islands. Cost of the 90-sq. mi. male annihilation program was 43¢ per acre for all materials and their application. Only about 3 wafers carrying a total of 35 grams of lure and 2 grams of poison were used per acre.

In Mexico a bait-chemosterilant combination was used in a 100 mango tree grove to control Mexican fruit flies, using one bait station for every two trees. Within 6 weeks 45% or more of the population was found to have taken up a green food dye that had been mixed with the tepa chemosterilant solution. Although the percent gravid females was not greatly reduced, compared to the control, the mango crop was protected for a period of four weeks during a period of high fly emergence.

#### F. Evaluation of Equipment for Insect Detection and Control

1. Subtropical Fruit Flies. A 30,000 curie, pool-type cobalt 60 unit was installed by the Atomic Energy Commission in January 1965, adjacent to the University of Hawaii's Food Science and Technology building. The unit will be used cooperatively by the University of Hawaii and the USDA for studies on disinfestation and shelf-life extension of Hawaiian fruits and vegetables. These studies will determine criteria for the possible design and installation of a semi-commercial unit, in the event practical quarantine treatments based on the use of radiation become available. Dose-distribution patterns in the 6"x16"x20" central canister and in the 3" tubes were determined by the Fricke dosimetric system. The dose rates were approximately 5 kilorads per minute in the canisters, used in the 3-tubes, on March 1, 1965. With this unit, 450 thousand fruit fly pupae can be irradiated at one time in about 2 minutes, compared to 1.5 hours in the old unit.

In Hawaii a low-cost trap made from a 1-gallon coffee can with plastic ends was equal to the standard Steiner trap in 14 weeks of testing. Five other designs of plastic traps with modifications in number, size, and position of openings gave catches ranging from 18 to 60% less than the standard.

#### G. Insect Control Treatments for Commodities Regulated by Plant Quarantines

1. Subtropical Fruit Flies. In Hawaii 50° F was found to be the minimum effective temperature for ethylene dibromide fumigation of a 72% load of packaged papayas infested by the Mediterranean, melon, and oriental fruit flies when the dosage was 24 oz/1000 ft<sup>3</sup> for 2 hours and treatment was followed by an aeration period of 3 hours at 60° F and then by refrigeration at 40° F for 1 to 3 days. The egg and larval population estimated from pupae developing in untreated fruits was 152,000. No survivors were found after 24 oz/1000 ft<sup>3</sup> fumigation: (a) At 50° F followed by 24 hours of aeration and refrigeration at 40° F, (b) at 50° F followed by 3 or 24 hours of aeration and refrigeration at 50° F, (c) at 60° F followed by 3 or 24 hours of aeration and refrigeration at 48° F, (d) at 40° F followed by 24 hours of aeration and refrigeration at 40° F. There were two survivors in a population of 14,000 after treatment at 40° F followed by 3 hours of aeration and refrigeration for 3 days at 40° F. No survivors have occurred after treatment at 1 lb/1000 ft<sup>3</sup> for 2 hours at 70° F followed by 1 hour aeration at 70° F and refrigeration at 40° F. Limited data indicate that treatment with methyl bromide at 2 lbs/1000 ft<sup>3</sup> for 3½ hours must be conducted above 50° F.

In Hawaii Dancy-type tangerines, packaged in cardboard orange cartons, were unaffected by fumigation treatments with EDB of 30-72% loads at doses of 24 or 48 oz/1000 ft<sup>3</sup> for 2 hours at 40-70° F following 6-7 days of refrigeration at 40-50° F. There was an increase of stem-end decay in navel oranges treated at 48 oz/1000 ft<sup>3</sup> and 40° F. Tangerines tolerated methyl bromide at 2 lbs/1000 ft<sup>3</sup> for 3½ hours but navel oranges became pitted. Bluefield and apple bananas in ventilated wooden boxes were uninjured after treatment of 50-75% loads with EDB at 12 oz/1000 ft<sup>3</sup> for 2 hours at 70° F followed by 6 days of refrigeration at 55° F. However, the rate of coloring was accelerated by the treatment. Methyl bromide scalded the banana rinds at 2 lbs/1000 ft<sup>3</sup> for 3½ hours at 70° F. Dancy-type tangerines were tolerant of hot-dip treatments of EDB in 100 gallons of water at 300 g for 5 minutes at 100° F, 170.3 g for 5 minutes at 115° F, 117.7 g for 10 minutes at 110° F, 106.0 g for 10 minutes at 115° F, 73.1 g for 15 minutes at 110° F, and 132.5 g for 20 minutes at 115° F.

In Hawaii 20-minute dip treatments of papaya at 115° F were ineffective at doses up to 54.8 g per 100 gallons of water (1:15,000 by volume) when the treated fruits were rapidly cooled to 65° F. No survivors were obtained at 109.5 g per 100 gallons (1:7,500), with rapid post treatment cooling.

In Hawaii the minimum dose of radiation required for disinfestation of fruits was found to be 21 kilorads for mature larvae of fruit flies and 76 kilorads for mango weevils extracted from the seeds. When packages containing fruit are treated, the doses must be corrected for attenuation, due to absorption by the fruit and packaging material. Refrigeration at 40° F before and/or after treatment reduced the formation of fruit fly puparia by approximately 93-98%. Weevils were moribund 0.4 to 1.3 months earlier than those not refrigerated. Ability to pack and chill fruit, as soon as picked, irrespective of time of application of the disinfestation treatment, will give the irradiation method another distinct advantage over fumigation or dip procedures.

In Hawaii poor flavor and aroma and severe scalding of the rind was found in Dancy-type tangerines when treated with 24-49 kilorads of gamma radiation at room temperatures and then refrigerated at 40° or 50° F for 4-7 days. Injury was avoided and only the increase in the rate of coloring was apparent when fruits were kept 4 days at room temperatures. Navel oranges were uninjured by post-treatment refrigeration after doses up to 49 kilorads. Apple bananas were uninjured by 24 kilorads. Bluefield bananas, probably because of less maturity, were scalded in the rind but the flavor and internal appearance were unaffected. Covering the bananas during growth did not improve the tolerance to post-treatment refrigeration.

2. Mango Weevil. The reproductive organs of adult weevils removed from seeds and irradiated at 10 and 15 kilorads in Hawaii recovered to normal size and functions 15 days later when compared to those in unirradiated weevils. Ovaries and testes exposed to 20-100 kilorads shrunk gradually with no sign of recovery.

3. Other Insects. At Hoboken, N. J., HCN fumigation at 1 pound per 1000 ft<sup>3</sup> for 2 hours under high, sustained vacuum near 70° F gave complete control of the methyl bromide-resistant Cecidomyid, Plemeliella abietina, and a seed chalcid, Megastigmus sp., found infesting spruce seed imported from Europe. HCN at 2 pounds for 2 hours without vacuum was also effective against Plemeliella but some Megastigmus survived. Four species of dry conifer seeds, including spruce, showed good tolerance to HCN as high as 2 pounds for 2 hours under vacuum. Carbon disulphide at 8 pounds for 24 hours also showed good insecticidal efficiency and seed tolerance. Ethylene oxide-carbon dioxide 10:90 mixture was effective against both insects at 25 pounds for 24 hours at normal air pressure but injured some conifer seed severely. Carbon tetrachloride at 58 pounds for 16 hours was found to injure a number of dry conifer seeds and its use on conifer seed is to be eliminated from the Plant Quarantine Treatment Manual.

At Hoboken, N. J., Japanese beetles entrapped in wheat were effectively controlled in small-scale tests by carbon tetrachloride-carbon disulphids 80-20 mixture (by volume, Vertifume) at a rate of 4 gallons per 1000 bushels for 4 hours or 3 gallons for 5 hours near 80° F. Complete kill also was obtained in a few tests at 4 gallons for 2, 2½, or 3 hours. The carbon disulphide was found to aerate completely from the wheat within 24 hours but some carbon tetrachloride concentrations (above the maximum allowable) were still present after 72 hours aeration. The latter finding is important from a safety aspect.

#### H. Varietal Evaluation for Insect Control

1. Citrus Scale Insects. Surveys of Dancy tangerine plantings intermixed with orange and grapefruit at Orlando, Fla., showed that this variety is apparently resistant to attack by citrus snow scale. No infestations were found on the tangerine trees even though they were often surrounded by heavily infested orange or grapefruit trees. In many instances, rough lemon rootstocks on the tangerines were highly infested with a marked line of demarcation at the bud union.

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## ORNAMENTAL SHRUB, FLOWER, AND TURF INSECTS

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Problem. Ornamental shrubs, flowers, and turf are damaged by the feeding of a variety of insects and mites. They are also damaged by a variety of diseases spread by insects. More effective and safer control measures are needed for many of these pests. Knowledge of the basic distribution of insect pests of these plants and information on their biology are required to provide a sound basis for the development of practical, effective, and safe control measures. Insecticidal and cultural methods of control that will not affect adversely the growing plants or natural enemies of the pests or result in objectionable residues are needed. The nature and cause of resistant strains of insects and mites and means of overcoming or preventing their resistance to insecticides require continuing investigation. The role and use of biological control agents should be more fully explored and efforts made to integrate biological control with insecticidal and cultural control methods. Use of controlled light and other physical factors as possible means of controlling greenhouse pests should be studied. Increased emphasis should be placed on the search for insect attractants, chemosterilants, and growth or reproduction-affecting substances.

### USDA AND COOPERATIVE PROGRAM

The Department has a long-range program of basic and applied research on insect and mite pests of ornamental shrubs and flowers at Beltsville, Md., Farmingdale, N. Y., and Sumner, Wash., in cooperation with State Experiment Stations of Maryland, New York, Oregon, and Washington, and with the Crops Research Division; and on turf insects at Moorestown, N. J., and Geneva, N. Y., in cooperation with the State Experiment Stations of New Jersey, New York, and Michigan, and the Northern Utilization Research and Development, Plant Pest Control, and Agricultural Engineering Research Divisions of ARS. Research on turf insects is also conducted under grant with the University of Florida.

The Federal scientific effort devoted to research in this area totals 8.4 professional man-years. Of this 1.4 man-years are devoted to basic biology and nutrition; 1.8 to insecticidal control; 1.0 to insecticide residue determination; 0.7 to biological control; 2.4 to insect sterility, attractants, and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; 0.4 to insect vectors of diseases; 0.1 to insect control treatments for commodities regulated by plant quarantine; and 0.5 to program leadership.

In addition Federal support of research in this area under grant provides for 0.4 professional man-year devoted to basic biology.

## PROGRAM OF STATE EXPERIMENT STATIONS

The research program in the States on insects affecting ornamental shrubs, flowers and turf is providing valuable information. Surveys are being conducted to determine the occurrence and abundance of insects and mites and their natural enemies. Investigations are underway to evaluate the extent and amount of damage caused by injurious species. Studies of seasonal life histories form a basis for developing practical control measures. Insects are reared in the field and collected for laboratory observation on the duration of life cycles in relation to temperature and other environmental factors. This information is used to determine which types of control methods would be used for most satisfactory results.

Principal emphasis is placed on chemical controls due to (1) the sporadic nature of insect and mite attacks on many ornamental plants; (2) the need for extremely effective control in nurseries to prevent dissemination of pests; and (3) the comparatively permanent nature of plantings of most ornamentals and turf grass which prevents the use of many cultural control methods. As new chemicals become available, they are evaluated for safety phytotoxicity and effectiveness in controlling injurious insects. Various formulations, schedules, concentrations and application rates are tested. Recently, increasing emphasis is being placed on the use of systemic insecticides on ornamentals because of their greater ease of application and reduced environmental toxicity hazard.

Resistance of certain mite species to control chemicals also is being studied. The incidence and degree of resistance is being determined, and the morphology and physiology of affected strains of mites studied to identify the factors responsible. Biochemical methods are being employed to determine differences in physiological systems not observable in behavior and morphological studies.

The State stations are devoting 19.6 professional man-years to the research in this area.

### A. Basic Biology, Physiology, and Nutrition

1. Orange Tortrix. At Sumner, Wash., orange tortrix males and females caged individually without food or water lived an average of 11 and 13 days, respectively. When given access to a 5% sucrose solution, the life span was increased by 6 days for the males and 3 days for the females. When single laboratory reared virgin males were caged with 1, 2, 3, and 4 virgin females, the bursa copulatrix yielded 2, 2, 5, and 6 spermatophore, respectively, indicating multiple mating had occurred in both sexes.

2. Japanese Beetle. Clear polyethylene bags (8" x 15½") were suitable containers for rearing grubs in New Jersey. One thousand grams of soil placed in each bag could maintain 50 to 75 third-instar grubs. Wheat was satisfactory as a food, providing more roots for feeding large grubs than

red-top clover mixtures. Third-instar grubs collected from the field were successfully reared to the adult stage with wheat roots as food; newly hatched grubs were reared to the second-instar. A medium of sterilized soil, peat moss, and peat moss with vermiculite seeded with red-top clover has given a 90% survival of grubs to the second instar.

A screened cage was developed which facilitates collection of eggs, cleaning and storing, and permits the use of plants as food sources. Giant smart-weed foliage has proven to be an excellent host plant for maintaining caged adults, and preferred to the fruits of plum, peach, and apple formerly used. Caged adults did not feed on asparagus foliage or plants and fed only sparingly on rhubarb.

3. European Chafer in New York. Seven and one-half percent of larvae reared in soil seeded with rye grass and clover that was watered daily transformed to adults. One hundred first-instar larvae were obtained from 136 reared adults. Chafers remain in the third instar 260 days in nature; are dormant 70 to 80 days of this period. In the laboratory this period was reduced to 168 days and adults emerged in mid-April instead of mid-June. No diapause was encountered.

4. Pentac Useful in Insect Culture. In Maryland, Pentac controlled spider mites on host plants used to rear the omnivorous leaf roller, Platynota stultana, without damage to the leaf roller. Spider mites often cause rapid decline of host plants before leaf roller larvae can mature, thus interfering with biological studies. In tests of acaricides with low insecticidal activity for protecting the host plants from spider mites, Pentac, binapacryl, and Morestan each in sprays at 0.5 lb/100 gal had no apparent effect on half-grown leaf rollers reared to maturity on the sprayed plants. However, 98% of newly hatched larvae accepted Pentac-sprayed plants compared to 90% on untreated, 56 on binapacryl, and 80 on Morestan. Binapacryl exhibited a repellent effect with reduction in larval feeding and Morestan a slight toxic effect with smaller, less active larvae. Pentac appears to be the preferred differential acaricide, and will doubtless be useful in the laboratory rearing of other insects.

#### B. Insecticidal and Cultural Control

1. Zectran Controls European Corn Borer on Rose. In Maryland conventional fumigants and hand cutting failed to prevent severe losses caused by the feeding of this insect in stems and flowers of greenhouse roses. Zectran at 6 ounces per 100 gallons of emulsion spray gave excellent control. Larvae in tunnels were killed when they came in contact with residue around the tunnel entrance.

2. Poinsettia Insecticides. In Maryland weekly applications of dichlorvos aerosol were effective against whiteflies, soft scale, citrus mealybug, and Lewis mite. Weekly applications of binapacryl wettable powder spray controlled spider mites. Single applications of Meta-Systox-R emulsion gave

general protection against insects and mites. The materials were effective without leaving objectionable residues or causing injury to these highly sensitive plants that are injured by most insecticides.

3. Phytotoxicity Traced to Solvents in Insecticide Formulations. Severe growth-regulator injury or necrosis and chlorosis on chrysanthemums, poinsettias, and petunias sometimes follow the application of commercial preparations of dichlorvos, diazinon, Di-Syston, or Meta-Systox-R in thermofogs, mechanical fogs and mists, or conventional sprays. Investigations in Maryland disclosed that plant injuries can be reproduced by certain accessory materials present in the formulations. In tests with mechanical fogs certain methylated naphthalenes alone or combined with dichlorvos caused severe growth-regulator injury on susceptible chrysanthemums. A highly refined kerosene (Deobase) alone caused severe necrosis on Shasta chrysanthemum and lima bean. Methylene chloride formulations with dichlorvos caused no injury to the same crops. Results of these tests are influencing commercial formulators of greenhouse insecticides to modify their products.

4. Japanese Beetle. Field tests in North Carolina made by the Moorestown, N. J., laboratory indicated that control of Japanese beetle grubs in sod can be obtained with 8 pounds of diazinon per acre.

5. Tulip Bulb Aphid Controlled on Iris. In greenhouse tests in Washington, Meta-Systox-R and dimethoate applied at 2 pounds per 6-inch acre to iris bulbs when planted in flats gave excellent control of the tulip bulb aphid.

6. Spider Mites on Roses. In foliage sprays applied to outdoor roses at Beltsville, Kelthane, binapacryl, and dimethoate were superior to Pentac against nonresistant mites. Against resistant mites Kelthane and binapacryl were also highly effective but dimethoate failed to give control and was about equal to Pentac. The addition of 2% dimethyl sulfoxide to the four acaricide sprays provided no consistent enhancement of toxicity or persistence of effectiveness.

#### C. Insecticide Residue Determinations

1. Benzene Hexachloride Residues in Soil Toxic After 7 Years. This insecticide was applied annually at 16 pounds gamma isomer per acre for 5 years ending in 1957 in New York plots. Snapdragons planted 7 years later were reduced 22% in growth by the residues still present in comparison with snapdragons grown in replicated untreated plots. Double this dosage of gamma isomer applied as lindane did not affect growth. The insecticide residues tended to increase the growth of carnations.

#### D. Biological Control

1. Plant Traps Insects. Araujia sericifera, a climbing vine native to Brazil and Argentina, is grown throughout the world as an ornamental and

sometimes to catch insects. Captures at Beltsville, Md., in the flowers of this plant included 14 species of Lepidoptera mostly cabbage looper, corn earworm, tobacco budworm, and the alfalfa looper, and numerous ants and an occasional honeybee. The moths, when feeding on nectar in the flowers, are caught when the proboscis becomes wedged between a pair of finger-like processes at the base of each stamen.

Observations at night by flashlight indicate that flowers of this plant are not highly efficient moth or insect catchers since only a small proportion of the insect visitors are captured. However, the flowers are highly attractive to many species of economic pests especially noctuids, even in presence of Jimson weed, tobacco, and petunia. The flowering plants or the flower extracts may be of value as a decoy in connection with use of sterilants, poison baits or black light traps.

#### E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sex Lure in Orange Tortrix. In further studies at Sumner, Wash., a crude sex lure was extracted from copulating moths with methylene chloride. When a trap containing a filter paper impregnated with 100 female equivalents was placed in a 2 x 3 foot cage containing 25 3-day-old virgin males, 21 percent of the males were caught in 40 hours. Studies on the purification of the sex lure have been initiated.

2. Japanese Beetle. At Moorestown, N. J., it was found that tepa-treated beetles released in the field soon after treatment will not augment populations because of slow action. Field beetles, after treatment with tepa, become sterile within 24 hours. Tepa-treated male beetles are capable of competing sexually with untreated males. Dipping beetles in .0625 tepa solution was as effective as applying 10  $\mu$ g topically, but reduced the longevity of males 15% and females 29%. Contact of males with tepa-coated surfaces momentarily resulted in a high degree of sterility. Increasing the ratio of fertile to sterile males caused a reduction in fertility that reflected the ratio of fertile and sterile males.

3. European Chafer. In studies with light traps in New York, Electrol-Lads 4500 V-5 ma, and Gardner 3500V-10 ma were ineffective for adult European chafers. Gardner Model 160-30 5000V-30 ma killed 37 to 57% of the chafer that struck the grid. There was an indication that chafer beetles "home-in" on an object silhouetted by the lamp rather than the lamp. A 20-watt black light captured about 6% of the total population of chafer in a tree prior to 11:30 p.m. or about 12% of the population estimated to be present during the entire night. Grid type lights killed about 4 to 6% of the population within a tree.

4. Aphid Traps. At Farmingdale, N. Y., a few more winged aphids were consistently caught in water in pans painted yellow all over than in pans painted yellow on the inside and sandalwood on the outside. Water or a film of grease inside pans trapped equal numbers of aphids but collection of

aphids from greasy films was difficult. The aphid catch was nearly doubled when a wetting agent was added to the water in the traps. In water with detergent, aphids were wetted, sank to the bottom of the pans, and became distorted and unsuitable for taxonomic study quicker than in water only. Federal or safety yellow attracted about 10% more aphids than a lighter yellow in field studies under natural light and in a flight chamber under fluorescent light, and more than a combination of fluorescent and black light.

5. Attractants for Thrips. In Maryland field tests, the color of zinc white paint on a sticky card was the most attractive of several colors to migrating flower thrips Frankliniella tritici Fitch. Other paints in decreasing order of attractiveness were vivid yellow, royal blue, titanium white, bright aluminum, shamrock green, white lead, crimson red, and flat black. Bright aluminum mounted below rose flower buds reduced invading thrips by 75%. Pink, yellow, and white rose blossoms were approximately equal in attractiveness. Deep orange and crimson red were less attractive than pink. Blending of colors in many rose varieties renders color preferences less distinctive.

6. Aluminum Sheets Repel Aphids. In tests in New York, trap catches of **flying** aphids were reduced 95% by sheets of aluminum coated paper placed on the ground on both sides of rows of gladioluses. Sheets on one side of rows were less effective. Incidence of aphid-transmitted cucumber mosaic virus (CMV) was also reduced by the protective aluminum sheets. Aluminum powder sprays on the soil lacked persistence and on the plants reduced plant growth.

#### F. Evaluation of Equipment for Insect Detection and Control

In cooperative greenhouse tests in Maryland and New York with low volume mist sprays and thermofogs, one unit (Klip-on fogger) was superior to others tested in that it discharged at high velocity uniformly fine particles of the insecticide for a distance of at least 100 feet in a greenhouse. This or similar mist spraying units are more versatile than thermofog generators and may replace some greenhouse aerosols.

#### G. Insect Vectors of Diseases.

1. Iris Mosaic. In preliminary studies in Washington, mild iris mosaic symptoms were obtained on seedling iris one year after inoculation by the English grain aphid and Rhopalosiphum padi. The test plants are being retained for another year's growth to see if more definite symptoms appear.

2. Cucumber Mosaic on Gladiolus. In New York, aphid-transmitted cucumber mosaic virus (CMV) in field plots of gladiolus was more serious in late season than in early season plantings, thus showing a distinct seasonal variation in transmission of CMV by its aphid vectors. Development of infections of CMV in gladiolus test plots declined rapidly as the distances

increased from 1 to 20 feet from plots heavily infected with CMV indicating the importance of short distance spread of the virus.

3. Virus Reduced by Aphid Repellant Aluminum Sheets. In small field plots, sheets of aluminum-coated paper placed on the ground on either side of gladiolus rows reduced aphid transmitted CMV (cucumber mosaic virus) infection to 8% and 7% in flowers and plants, respectively, compared to 40 and 37% respectively, in unmulched check rows. A sheet of aluminum on one side of row and aluminum powder spray on the foliage were less effective in reducing CMV infection. Aluminum sprays also reduced size of plant, flower and corm growth.

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## TILLAGE, PLANTING AND FERTILIZING OPERATIONS AND EQUIPMENT

Agricultural Engineering Research Division, ARS

Problem. Intensive research is needed to determine the optimum tillage requirements, based on costs and crop response, for various soil, climatic, and crop conditions. There is a need for studies on the precise seedbed requirements for various crops; for investigations on row spacing, placement of fertilizers, and fertilizer application equipment; for precision planting studies; and for automatic transplanting equipment.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program on planting methods, on means of applying fertilizer on various crops, and on tillage methods. Approximately 3.0 professional man-years are devoted to research on tillage methods, fertilizer placement and distribution equipment, seed and vegetable planting equipment, and transplanting and fertilizing equipment.

### PROGRAM OF STATE EXPERIMENT STATIONS

Many of the State agricultural experiment stations are engaged in both fundamental and applied research dealing with the development of new principles and the application of currently available knowledge to the problems concerned in soil-machine relationships in order to increase efficiency in crop production. Investigations are in progress on ways to develop and apply more efficient methods of soil manipulation that will produce improved soil physical conditions for seed emergence and optimum plant production; and development and evaluation of systems of tillage which offer possibilities in reducing time, labor, or equipment to produce a crop.

Problems concerned with planting of the many sizes and shapes of seed of agricultural crops, together with the introduction of fertilizers for use by these crops are under attack by many of the State Agricultural Experiment Stations. A considerable amount of this work is cooperative with the Department. These studies are concerned with the development of new principles that can be used to meter and place seed which could lead to planter improvement. Similar investigations are in progress to develop satisfactory metering and placement devices for application of liquid as well as solid fertilizers. In both instances, the principal objective is to provide the best possible means of seed and fertilizer placement which will assure healthy plant emergence with vigorous growth to maturity.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Effect of Tillage Practices on Plant Growth

The replicated plot work with primary tillage methods for potatoes was completed in the fall of 1963. Briefly summarized, the results of this study indicated that there were no advantages obtained with any of the primary tillage treatments tested as compared with planting potatoes in wheat stubble with no prior tillage. In fact, the highest average yield was obtained with no primary tillage.

B. Fertilizer Placement and Distribution Equipment

Eighteen experiments on the establishment of field crops and vegetables were put in cooperatively with various State, Federal, and commercial research units.

C. Vegetable Planting and Fertilizing Equipment (including potatoes)

After three seasons of cooperative fertilizer placement studies in Florida on four vegetables, only one vegetable crop gave no response. For example, on peppers, the use of a single band, or one  $2\frac{1}{2}$  inches on each side of plant row and  $2\frac{1}{2}$  inches below at time of transplanting increased yields of about 31 percent. However, efficient use of fertilizers on green beans and cucumbers responded to the use of high-low fertilizer positions (half of fertilizer  $2\frac{1}{2}$  x  $2\frac{1}{2}$ ; other half, same side width, but 6 inches deep). Special drill FJ 44 and special transplanter F 75 were used with the field experiments.

Cooperative studies with planting and fertilizing field crops and vegetable crops in the southwest area were conducted at six locations which are in the bounds of three states (Texas, Nevada, Arizona). The studies involved micro-nutrient studies with lister planting of cotton; macro-nutrient studies with cotton and potatoes; and fertilizer placement studies with potatoes. Four seasons of potato fertilizer placement experiments under irrigation practices in Arizona indicated that continuous bands 4 inches on each side and 2 inches below seed piece gave superior production. Yield increase ranged from 7 to 19 percent over other placement positions, which included the common placement of bands two inches on each side and on level of seed piece.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None.

## CROP PEST CONTROL TECHNIQUES AND EQUIPMENT

Agricultural Engineering Research Division, ARS

Problem. Many pests attack economic crops in the United States, resulting in billions of dollars of loss to the farmer each year. Plant diseases, weeds, insects, and nematodes are examples. Every method to control or eradicate any of these pests requires some type of equipment. Effectiveness of the equipment necessary may be essential to the success of the methods which are attempted or recommended. Thus, equipment to control a wide variety of pests on a wide variety of crops is required. There is also a need for improved methods of much greater efficiency for applying pesticides to plants and the soil.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, and mathematicians engaged in both basic studies and the application of known principles to the solution of farmers' problems. Cooperation is with the State Agricultural Experiment Stations of the states mentioned, unless otherwise noted. At Wooster, Ohio, basic research is conducted on fundamental studies of aerosols and on various spray formation devices. Soil fumigation research also is conducted at Wooster, Ohio. Chemical insect and disease control research is conducted at the Grain Insects Research Laboratory at Tifton, Georgia, chiefly on corn insects; at Ames, Iowa, particularly for corn borer control; and at Wooster, Ohio, on improved equipment for corn borer control. Disease control research is also conducted at Wooster, Ohio. Weed control research, chemical and cultural, is conducted at Ames, Iowa and Columbia, Missouri. Aircraft application equipment is studied at Beltsville, Maryland, in cooperation with the Forest Service; and at Forest Grove, Oregon, in cooperation with the Oregon and Washington Stations, on low growing crops. Pest control equipment research for vegetables is conducted at Forest Grove, Oregon.

The Federal scientific effort devoted to research in this area totals 19.0 professional man-years per year. Of this number, 1.0 is devoted to soil fumigation; 0.8 to insect and disease control by ground equipment in vegetables and other low-growing crops; 1.8 to aircraft equipment for application of pesticides to vegetables and other low-growing crops; 1.3 to aerial spray equipment for forest insect control; and 1.2 to program leadership.

### PROGRAM OF STATE EXPERIMENT STATIONS

Both basic and applied research investigations which have been designed to discover and develop methods, techniques, and equipment for control of the many pests that attack our economic crops are in progress at the several Agricultural Experiment Stations. Much of this work is cooperative with the Department.

These studies are involved in the complicated objectives of furthering the efficiency and the means for better control of insects, plant diseases, nematodes and weed problems through application of engineering knowledge on the use of aerial and ground chemical applicators for liquids and dusts, flame cultivators and mechanical devices for soil manipulation and soil fumigation.

A total of 2.7 man-years is devoted to this work.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Soil Fumigation

1. Experimental equipment was used to apply soil treatments, in cooperation with the Ohio Station, for development of a control of Verticillium wilt in strawberries, potatoes, eggplant, okra, tomatoes, and various other vegetables. Methods of controlling damping-off in nursery plantings, radish clubroot and control of populations of various nematode species in fruit and vegetable plantings were included in the experiments. The application of chloropicrin by equipment which sealed the fumigant under a polyethylene cover was fairly effective in controlling Verticillium in several vegetable plantings. This material is too expensive at this time for use on many crops. In-the-planter-row application equipment which placed a fungicide-insecticide formulation in the onion seed row at planting, produced some increases of over 50 percent in stands and yield increases over 20 percent. Cherry trees planted in some treatments made in 1957 and 1960 continue to show much better growth than check trees and lesion and pin nematode populations are lower in the treated areas.

Soil treatments were applied in Ohio for the study of residue remaining in the soil. In muck soil plots treated with the same chemicals for the past eight years, those receiving bromine compounds now show 68 ppm of bromine in one case and 56 ppm in another. The check shows 32 ppm. Onions will not grow in 68 ppm and yields of potatoes are greatly reduced. Yields of beets, spinach, and lettuce are also reduced. Celery and carrot yields are increased, probably because of root-knot control. At 56 ppm, onion yield has gradually been reduced and the crop failed in 1964. Yields of potatoes, beets, and spinach are also reduced. Celery, carrots, and radishes show no yield effect.

Liquid mulches were applied in Ohio to several vegetable plantings. The use of a zero pressure wheel to smooth the soil surface preparatory to mulch application produced better results than drag equipment. Seedlings penetrated the wax and asphalt applications better than a latex application. An application rate of about 400-450 gallons per acre seemed desirable for most ordinary vegetable plantings. Under the conditions of these experiments, soil temperatures under the black mulches were raised two to three degrees above those under unmulched surfaces and moisture contents were raised one to two percent for a few days. This apparently produced better seed germination and earlier maturity in a number of vegetables. This is particularly important in growing crops for sale on the early markets.

## B. Insect Control in Corn

1. Insecticide granules were applied for control of Northern corn root worm in cooperation with the Ohio Station, with equipment developed or adapted for small plot treatment. A fluted-type feeder gave extremely accurate application rates of a large number of different granular materials used. In one experiment using 12 different insecticides only one, heptachlor, was significantly better than the untreated check, yielding 18 bushels of corn per acre more than the check. No significant differences were found among the roots damaged and the number of plants that were lodged.

In investigations in cooperation with the Iowa Station, the major emphasis of the program was the screening of new insecticides, development of systemic insecticide control, and development of combined control of the European corn borer and corn rootworms. The results of these studies indicate that several experimental compounds may be as effective for borer control as presently recommended compounds. American Cyanamid 47470 was shown to be the most effective compound for systemic control of corn borers, however, Niagara 10242 demonstrated some activity. Experiments in 1964 show it is possible to combine the control of first-generation corn borers and corn rootworm larvae with one application of insecticide.

2. Ultrasonics are being investigated in Georgia as a possible means of controlling insects on southern grain crops without chemicals. Field work has been concentrated on repelling corn earworm moths, while laboratory work has been devoted primarily to destruction of eggs and larvae. Ultrasonics used in the laboratory did not reduce armyworm or earworm egg viability within an exposure time of five minutes or less. However, ultrasonics killed the first instar larvae of either the armyworm or earworm in less than 15 seconds.

Seeds of corn were oriented in Georgia at the time of planting to determine if the foliage and ears could be oriented and, if so, would the orientation effect insecticidal application for insect control. These tests did not show any orientation of the ears or foliage, with the ears growing about the same in each direction. Yields were slightly higher from the oriented rows. Insect damage was not significantly different between the oriented and unoriented rows, receiving the same insecticide treatments.

3. DDT was further evaluated in Georgia for its effectiveness in controlling corn earworms in sweet corn. Three plots were treated by recommended procedures with 2 lbs.DDT/A. One plot was treated every day, another plot was treated every second day, and the other plot was treated every third day. The plot receiving a treatment every day resulted in 66 percent worm free ears. The plot treated every second and third day had 50 and 53 percent worm free ears, respectively. Effective earworm control was not obtained.

A study was made in Georgia for determining residues and insect control in sweet corn when applying an insecticide in the form of a dust, liquid and granule. The dust was applied through nozzles positively charged with

13,200 volts of electricity, negatively charged at the same voltage, and uncharged. The emulsifiable concentrate liquid was applied by spraying and with a brush applicator. Spraying gave the best insect control, while the brush applicator was next. Granular form was decidedly the poorest. The brush applied more insecticide on the target area (ear tips) than the spray, and used 1.6 lbs. DDT/A against 2 lbs. DDT/A applied with the spray. Dust from positively charged nozzles gave the highest dust deposition.

### C. Weed Control in Corn

1. Several methods of applying preemergence chemicals for weed control in corn were used in investigations cooperative with the Iowa Station. Mixing granular and liquid formulations of atrazine, 2,4-D, and Radox T into the soil at planting time with rotary hoes, drag harrows or wire wheels did not improve the effectiveness of the compounds. With atrazine and simazine liquid preemergence applications gave better weed control than granular formulations. Granular and liquid formulations of 2,4-D and Radox T applied at planting time were equally effective. None of the preemergence treatments gave full season weed control, and one additional mechanical cultivation was required for band treatments.

Studies on equipment, techniques, and chemicals for directional postemergence sprays in corn were continued in Iowa. Results were erratic but did show that this practice has possibilities as a "salvage" operation. Studies on weed control practices for narrow-row corn indicate the need for little or no change in mechanical or chemical methods. Earlier soil shading with narrow rows resulted in improved weed control. Timely mechanical cultivations gave better weed control in narrow-row corn than most chemicals.

Early spring applications of atrazine and simazine in Iowa on plowed soil successfully controlled weeds in corn throughout the growing season without secondary tillage or cultivations. Similar applications on unplowed cornstalk ground were nearly as successful but required one mechanical cultivation.

Field studies were made in cooperation with the Missouri Station to evaluate different methods for directed applications of dalapon (1 & 2 lbs./A) for weed control in corn. Directed applications were made that varied from no leaf protection to maximum leaf protection provided by tying the leaves to the corn stalk. Three different applicators (a special shield leaf lifter, a wire leaf lifter and a special directed nozzle) were used in the study. Applications were made to corn under weed-free conditions so corn damage from contact with the dalapon could be evaluated. No significant corn damage was noted for any of the treatments. This is the first year of a three-year study where no damage occurred. This is thought to be due to the absence of rainfall after application this year. Additional studies will be made under both weed-free and weedy conditions. A field study was made to determine if incorporation of amiben (1, 2, 3 and 6 lbs./A) would allow its use for weed control in

corn. However, incorporation did not reduce the damage to the corn. All treatments resulted in lower corn yield than for the cultivated check treatments.

Field studies were continued in Missouri to determine the effectiveness of 8, 10, 12, 14 and 16-inch band applications, sprayed over the rows, of 2,4-D, simazine and atrazine for weed control in corn. In each case, the amount of active ingredient for the area actually covered was the same, resulting in a saving of chemical for the narrower bands. The middles between the rows received one cultivation, and it was more difficult to cultivate the plots that were treated with the narrower bands of spray. No significant difference in corn yield was noted for any of the band applications.

#### D. Insect and Disease Control by Ground Equipment in Vegetables and Other Low-growing Crops

1. Five series of comparative tests for control of Cercospora leaf spot on sugar beets were made in cooperation with the Ohio Station, using boom and nozzle-type hydraulic sprayers. In a timing and interval study, the fungicide applications were spaced at 10, 15, and 20 day intervals with number of applications ranging from three to seven. The untreated check plots were virtually defoliated in late August following a short rainy period and, though these beets grew new leaves, their sugar content was reduced. The sprayed plots decreased in disease count as the number of applications were increased. The yield in gross sugar per acre was greatest with the 10-day schedule using six spray applications. In an experiment comparing effectiveness of a series of copper compounds, all were effective in disease control with little significant difference between compounds. In a third experiment, five experimental fungicides were compared with maneb and an untreated check. One compound TRTH (triphenyl tin hydroxide) applied at 2 pounds per acre was most effective in disease control and gave highest gross yield of sugar per acre. In a fourth experiment, a series of maneb formulations were applied with different zinc compounds as supplements. The results were inconclusive. The use of zinc as an additive to maneb seems to add very little to the effectiveness of maneb used alone. In a comparison to four oils with tribasic copper, the results were inconclusive.

A series of experiments were conducted in Ohio with an air-blast sprayer for control of Cercospora leaf spot on sugar beets. The sprayer was an adjustable turntable type with capacity of 33,000 cfm and 80 to 90 miles per hour air velocity. The swath width was 50 ft. Comparative applications of copper fungicide were made at 40, 20 and 10 gallons per acre rates with 300 and 60 psi for each rate. Disease control and yield data were taken. Determinations were also made of swath pattern of the copper fungicide spray deposited across the swath for the purpose of correlating with disease control and yield. The swath pattern for 40 gallon per acre rate at 300 psi gave a heavier spray deposit at a distance from the machine than for the other tests. This was due to the nozzle arrangement and the use of a large jet nozzle at the top of the manifold. There was no significant

difference between 300 and 60 psi with the 20-gallon per acre rate. The 20-gallon applications gave the highest yields in tons of beets and gross sugar. At the 10 gallon per acre rate, 60 psi showed higher deposit of copper and also higher yields of beets and gross sugar than the 300 psi. The deposit pattern of sprays with air sprayers is changed or distorted by wind conditions at the time of application. The pattern can be changed and sometimes improved by adjusting the air outlet or changing position of nozzles on the outlet manifold.

E. Aircraft Equipment for Application of Pesticides to Vegetables and Other Low-growing Crops.

1. Extensive spray application tests were made in Oregon with a Bell D-1 helicopter in cooperation with ENT. The effect of boom length and location, height of flight and speed of application on the shape of spray pattern and swath width, were investigated. The shorter 26-ft. boom gave a swath width of about 40 ft. when the application height was from five to eight feet. Increasing the boom width to 48 ft. increased the swath width by a distance of about the increase in boom length. For the two boom positions tested, there was no appreciable difference in pattern shape or swath width due to boom location. Increasing the height of flight to 20 to 25 ft. compared with five to eight feet increased the swath width about five feet for the shorter boom, and about 12 ft. for the longer boom. The speed of flight made no appreciable difference in the swath width. These tests were made with a uniform nozzle arrangement. However, the variation in deposit across the swath indicate the need of additional tests with a nonuniform nozzle arrangement to obtain a reasonable uniform deposit rate.

Spray pattern tests were conducted in Oregon using a Pawnee PA-25-235 airplane with modified wing tips. The modification consisted of removing the taper of the wings and squaring the ends. A nonuniform nozzle arrangement was used which produced a reasonably uniform deposit across the treated swath. On the basis of these tests an application elevation of 10 ft. and a swath spacing of 65 ft. was recommended for pesticide applications to low growing crops with this airplane.

Two spray applications were made to field plots of corn in Oregon with a Bell 47 D-1 helicopter to determine the effect of speed on spray penetration and rate of distribution. The speeds used were 30 and 57 mph. The height of the helicopter skids above the crop was from three to five feet. A 26-foot boom was used resulting in a swath width of about 39 ft. The mean recovery rates of spray as measured from sampling plates in the open were 8.9 gpa at 30 mph and 5.6 gpa at 57 mph. Almost 50 percent of the top leaf areas had deposits greater than five gpa for the 30 mph application speed compared to 19 percent for the 57 mph speed. About 86 percent of the underleaf sampling areas received 0 to 1.0 gpa deposit at the 30 mph speed compared to 62 percent for the 57 mph application speed.

## F. Aerial Spray Equipment for Forest Insect Control

1. In spray distribution tests with the TBM (torpedo bomber) airplane, which were made at Beltsville, Maryland, in cooperation with the FS, a long underwing spray boom did not produce an appreciably wider swath at deposit levels generally used in forest spraying than did a shorter trailing edge boom. From the equipment operation standpoint the short boom on the trailing edge of the wing is to be preferred over the longer underwing boom.

A series of test flights were made at Beltsville to secure drop spectrum samples for measurement of the atomization of water sprays. A Piper PA18A at 80 mph was used with T8010 nozzles directed forward and down 45° to the thrust line of the plane and at 25 psi spray pressure. These nozzles are the ones currently recommended for atomization of 150-160 microns mass median diameter with oil sprays. An average of the data from five flights showed an mmd of 300 microns - about twice that of oil sprays. The difference was greater than expected and may be caused by the higher evaporation rate of water spray as compared to oil. It is expected that with additional tests a factor can be developed to allow conversion of D-max to mmd similar to that previously worked out for oil sprays.

Investigations by other workers have shown that electrostatic charging of dusts results in more effective deposition. The behavior of electrostatically charged spray drops was studied at Beltsville with respect to the atomization, distribution and foliage coverage of the spray. A rotary type laboratory spray apparatus was devised to charge the drops in a water spray as it was atomized. The charge could be made either positive or negative. The range in drop size was much narrower in a charged spray than in uncharged spray thus providing some degree of control of spray drop size. The charged spray cloud expanded as it left the apparatus. Apparently like-charged bodies were repelling each other. This action should produce a more uniform distribution of spray. The presence of a charge increased the amount of spray deposited on foliage from observations when charged spray was released above a small potted tree that was electrically grounded. A set of four spray charging devices have been designed for mounting on an airplane for further studies of use of this type of equipment.

## J. Foreign Research Under Public Law 480 Funds.

1. A three-year research contract under PL 480 funds with the Agricultural Research Station, Beit Dagan, Israel was executed in September 1964 to improve the penetration of insecticide sprays into the dense foliage of citrus trees. Most of the first six months have been spent in assembling and constructing equipment and apparatus necessary to the project.

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## CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT

Agricultural Engineering Research Division, ARS

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting and farm handling crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

While research on harvesting equipment and methods has led to much improvement in the reduction of production costs of such crops as grains and forage, much additional work needs to be undertaken, both basic and developmental, in order that all crops may be mechanically handled. Harvesting equipment research for fruits, only recently initiated, has already resulted in sizable cost reductions, but the potential savings for these crops and vegetables are enormous.

The problems associated with harvesting and handling are interrelated with crop growing, processing, and storage thus necessitating close cooperation with engineers in other research areas and with scientists in other disciplines.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research is being conducted at Lake Alfred, Florida; Davis and Riverside, California; in cooperation with the respective State Experiment Stations. Research on deciduous fruit harvesting equipment at East Lansing, Michigan; Wenatchee, Washington; and Davis, California; is cooperative with the Experiment Stations in those States, and with producers, and machinery manufacturers. Crops under study include: Apples, pears, peaches, apricots, plums, grapes, blueberries, cherries, and dates. Potato harvesting research, cooperative with the Red River Valley Potato Growers' Association, is being conducted at East Grand Forks, Minnesota.

The Federal engineering effort devoted to research in this area totals 27.4 professional man-years. Of this number 4.0 are devoted to citrus; 5.5 to deciduous fruit; and 2.0 to potatoes.

## PROGRAM OF STATE EXPERIMENT STATIONS

Most of the state agricultural experiment stations are engaged in some aspect of basic or applied research which is concerned with improving machines and methods for efficient harvesting and farm handling of the many economic crops which make up the total national agricultural production. Much of this research effort is cooperative with the Department.

Detailed investigations are in progress to develop reliable mechanical harvesting and handling equipment as well as ways in which improvements might be made in crop production systems to increase yields, product quality and overall efficiency.

Current research is concerned with the diverse problems involved with these specific crops: All small grains, including rice and field corn; cotton, peanuts, castor beans, and safflower; citrus, apples, peaches, olives, apricots, cherries, prunes, cranberries, coffee, grapes and pecans, green-cut forages, hay and seed crops; cabbage, lettuce, asparagus, tomatoes, Irish potatoes, sweet potatoes; blueberries, peas and sweet corn; tobacco; and sugarcane.

During the course of these engineering investigations close cooperation is maintained with research scientists who have responsibilities for making improvements to these crops. This activity is most important in order to have machines and systems that are compatible with the new developments.

A total of 44.2 man-years is devoted to this work.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Citrus Harvesting Equipment

1. Harvesting citrus. The rapidly decreasing availability of suitable domestic labor for picking citrus and the termination of the off-shore labor and bracero programs have created a serious need for improved methods and equipment for harvesting citrus fruits.

In Florida, time of harvest trials with the tree shaker and catch frame harvest method continued in Valencia, Hamlin, and Pineapple oranges and Marsh grapefruit. A new tree shaker was designed and built which increased fruit removal. Another catch frame and shaker were constructed to match the previously built equipment to form a complete harvesting system. Tentative work rates and harvest cost data were established and this system is ready for commercial use when the need arises. The effects of limb size, hanger length, shaker frequency, and amplitude on fruit removal and stem retention were studied and data used in the tree shaker design.

A comprehensive fruit quality study was undertaken and results are not yet complete. Contract research was initiated on pruning for mechanical harvesting and use of chemical looseners to improve fruit removal. The compound, iodoacetic acid, showed considerable promise in loosening Hamlin and Pineapple oranges, thus reducing shaking time and attached stems.

The oscillating air blast harvesting trials were continued on a limited basis. The main problem is evaluation of tree damage and this has not been evaluated as yet by the horticulturists. The FMC-2 prototype air harvester is undergoing tests to determine optimum ground speed and air oscillation rates. Air volume and velocity were increased over last year's model. Fruit quality data with this method of harvesting are also being accumulated.

A number of tree wall pruning plots were put in (both young and old trees) for picking trials with both the ladder and bag method and picking platforms. The project has worked with a number of manufacturers and inventors trying to develop new ideas and equipment for citrus harvesting. Our fruit blocks and facilities have been made available for test work on numerous occasions.

In California, the effect of direct current electric power through citrus trees on causing abscission of the fruit is being investigated. Voltages of 6 to 120 are being used. The natural potential of trees is being determined. Much information on flow of nutrients through the tree is being obtained and this research is very promising.

An inexpensive man-positioning device has been designed and constructed and also looks promising. It is self-propelled and the movement is based both on linear and curvilinear cylindrical coordinates. A pulsating vertical air flow harvesting unit has been designed and constructed and will be tested. Two mass removal devices (one using oscillating tines, the other rotating stripping tines) were constructed and tested. From 85 to 99 percent of the fruit was removed. However, 10 to 25 percent of the fruit was split. A vacuum twist unit for removing individual oranges was made and moved into the tree on a staggered grid pattern. Removal rates of 55 to 85 percent were obtained. In an attempt to reduce the distance of fall and thereby reduce the damage to the fruit in falling through the tree from a mass removal method, an intermediate catching device was developed and tested. This collecting device consists of a series of half-cylindrical troughs mounted parallel. These were cantilevered on coil springs to permit deflection so as to slide by the limbs upon penetrating the canopy of the tree. The troughs are inclined to permit the fruit to roll to the rear. For tests with oranges, this collecting device caught an average of 85 percent of the fruit with a range for the tests from 70 to 100 percent. The preferred mounting arrangement would be to have the troughs in two horizontal planes with the lower troughs beneath the spaces between the upper troughs.

Several methods of sensing devices were investigated. Spectral analysis of the reflectance of fruit, leaves, and bark revealed a ratio of approximately 10:1 between the relative reflectance of ripe oranges and leaves at a wavelength of 670mu. An experimental detector was constructed which utilized a

long tube to limit the field of view from which light was reflected into a phototube. It was designed to limit the field to one orange at a distance of 25 feet from the tree. Optical filters with a peak wavelength of 657mμ and 685mμ were used individually to measure the reflected light at the two wavelengths. Both wavelengths were near the range found to be optimum for differentiating between ripe oranges and leaves. It was shown that fruit against a background of leaves could be detected at distances up to 25 feet when adequate light was present. Fruit on the perimeter of the tree on the side exposed to sunlight was adequately lighted. Fruit back in the tree and that on the shaded side was more difficult to detect. An artificial light source could be used to overcome this deficiency.

Several models of clippers were designed for single clipping. One model was field tested on Lisbon lemons and commercially tested on Eureka lemons. The stem cut was excellent and close to the button without cutting the button. Picking rate, using the test models, was felt to be lower than that of other previously developed single clip clippers.

Studies were initiated to determine the exact location of the fruit in the tree. For a 15 foot high Valencia orange tree, 89 percent of the fruit was in the zone from 2 to 12 feet above ground and 92 percent was within 3 feet of the mean radius of the exterior of the canopy at the respective fruit height.

#### B. Deciduous Fruit Harvesting Equipment

1. Harvesting grapes. About 225,000 tons of Concord grapes are produced each year in the States of New York, Michigan, Washington, Arkansas, Pennsylvania, and Ohio. Conventional harvesting and handling methods are expensive and cause considerable damage to the raw product. Research showed that grapes could be harvested with hand-held shakers and bunch grapes handled in pallet boxes. A report on the bulk handling studies and a grape box pick-up machine was published. This line project is being closed out June 1965.

2. Harvesting clingstone peaches and apricots. Hand labor for harvesting tender flesh fruits is scarce and may not be available in the near future. Previous research has shown it is feasible to mechanically harvest cling peaches and apricots. Last year the mechanical properties of clingstone and freestone peaches, apricots, pears, and apples were studied. Pears can withstand a large compression force relative to the other fruit and, therefore, present the least problem of bruising of fruit in the bottom of bulk containers. Apricots, particularly very mature ones, are bruised by a relatively small compression force and, therefore, are more subject to bruising in bulk bins. Pears have a relatively large yield deformation, especially when compared to apples. This indicates that, when fruit is placed in a confined space (for example, a box for fresh shipment) and then deformed (as when the lid is applied to the box) apples are much more likely to be bruised than pears. Apricots and peaches have a much lower stiffness than either apples or pears, and the low stiffness results in a

low natural frequency when the fruit is in containers. This low natural frequency often results in excessive movement and associated bruising of top fruit during transit, since they frequency correspond with the natural frequencies of transport vehicles. Therefore, pears and apples are less likely than either peaches or apricots to present problems on injury to the top fruit in containers. Studies showed that apples are more susceptible to impact bruises than peaches or apricots. Maturity affects mechanical properties of fruit and, therefore, time of harvest is important.

3. Harvesting dates. Dates grow on palm trees which are 30 to 50 feet high and it has become almost impossible to find workers to handpick fruit from these tall trees. Engineering help was given to growers and others in constructing mechanical harvesting equipment designed after the equipment and methods developed on this project. About 12 million pounds of fruit (one-third of total crop) was harvested mechanically this season. It appears that this will be increased to at least two-thirds of the crop next year. The bunch-cutting method of harvest will be the major method used. This project is being terminated May, 1965.

4. Field grading apples. Growers store millions of bushels of apples "orchard run." This means that many hundreds of thousands of bushels of undergrade fruit are stored in CA or regular storage and then sorted out and sent to cider mills or other low return outlets. A mobile field grader composed of a receiving belt, two eliminator sections, a sorting roller and a bulk bin filler was designed, constructed, and given preliminary tests. Results indicate thousands of dollars could be saved. The unit is being redesigned and will be given extensive tests and a report prepared.

5. Harvesting apples. Apples bruise easily and must be handled with care when harvested for fresh market. This type of picking is difficult, time consuming, and it is becoming difficult to recruit labor. Techniques and machines which will make it easier and less costly to harvest apples for fresh market are needed. Three sizes of trees (standard, semidwarf, and dwarf) were picked by the same picker without the use of any picking aids other than the conventional ladder and picking bag. The only apparent variables were tree size and planting arrangement. Compared to the rate obtained in standard trees, a 20.5 percent increase occurred in semidwarf trees and an increase of 17.0 percent resulted when picking dwarf trees in a hedgerow planting. In an effort to further increase picking rates on hedgerow plantings of semi and dwarf trees a self-propelled unit is being constructed. Support for two pickers as well as a fruit conveying system has been provided. The unit will allow two pickers to pick continuously while being transported past the hedgerow of fruit.

6. Over 40 percent of the apples produced in the United States are now processed. Growers only receive \$.80 to \$1 per bushel for apples and profits are small. Present picking costs of \$.20 to \$.25 per bushel need to be reduced. The McIntosh and Spy apples which were shaker harvested and stored for 6 months were graded and compared to handpicked fruit. The results indicated as in previous work that processing apples can be harvested with tree

shakers. However, more research is needed to determine details of holding times, handling methods, etc. This work will be continued in cooperation with a commercial processing company. The feasibility of using an endless air mat belt catching frame was investigated. A model was built to test the principle of dropping fruit onto a rotating air mat which would catch the fruit and subsequently convey it to the discharge end of a catching frame. Operation over level terrain appears practical, but additional trials with a full-scale prototype operating in various conditions are needed. Shake harvesting trials were performed on standard size trees of Golden Delicious, Red Delicious, and Winesap apples. The extent of fruit damage and type of separation were noted. Shake harvesting of Golden Delicious fruits does not appear feasible even for processing outlets since almost 42 percent of those removed by shaking had incurred some type of skin break. Red Delicious and Winesap apples destined for processing outlets have a much higher shake harvest potential.

7. Harvesting blueberries. Cultivated blueberries are grown commercially in the Midatlantic States, Great Lakes area, and the Pacific Northwest. Although this project has developed equipment and methods which greatly reduce the cost of harvesting and packing blueberries, costs are still rather high. A continuous-type blueberry harvester should reduce picking costs even further. Consulting service was given to several companies who are trying to develop a continuous-type harvester using the principle developed on this project. Progress has been slow and a commercial unit is not in sight. The second year of a 3-year study of the effect of mechanical picking on yields was made. Results show the yield per bunch is lowered but not significantly. Last year over 50 percent of the Michigan blueberry crop was harvested mechanically.

8. Harvesting cherries. Last year over one-half of the gross returns of tart cherries which were harvested by hand were paid to workers. These workers are becoming increasingly hard to recruit, a situation existing in all cherry-producing areas. The purpose of this research is to reduce harvest costs and labor requirements through mechanization and at the same time maintain quality of the fruit. Commercial harvesting equipment was studied and 32 changes in design were suggested in order to improve reliability of the equipment and to reduce bruising. Manufacturers are incorporating all changes in their 1966 equipment. The results of the 1964 study of electric sorters were published and as a result the 1965 units were modified. We again studied units in ten separate plants and a report will be made available. The units have been improved to the extent that cost of sorting is lower than hand sorting and the sorting efficiency satisfactory. A destemmer was designed in cooperation with a commercial company and five units constructed. It, along with three other available destemmers, were evaluated. The experimental unit did a satisfactory job and had a per ton cost of from one-third to one-sixth less than the other units. It will be improved and tested for one more season before being put on the market for sale to processors. The study of cushioning materials was completed and a report published discussing available cushioning materials--their advantages and disadvantages. This report has had wide demand by manufacturers,

growers, processors, and other researchers. A study of bruising showed that rebruising is serious and often occurs at receiving stations and the processing plants. Rebruising can result in soft cherries. A cherry hydro-cooler was designed, constructed, and tested. This unit cooled cherries from 70° F. to 40° F. at a rate of 1.5 tons per hour. Further research is needed to determine whether hydro-cooling is desirable.

A study of physical and thermal properties of cherries was initiated. Measurements of density and specific heat were made for a wide range of cherry sizes and soluble solids. Results showed average density for the whole cherry to be 1.05 gm./c.c. and specific heat .88; for the flesh, density 1.04 and specific heat .91. These studies will be continued and a comprehensive report on cherry properties published.

9. Harvesting prunes. Although research on this project has led to the adoption of mechanical harvesting in the Sacramento Valley, prunes are still harvested by hand in the Santa Clara Valley where prunes fall to the ground as they mature over a month period. Tests to determine fruit removal as affected by shaking trees at the trunk in more than one direction were conducted in two orchards of different age and structure to obtain tree variation effects. One orchard was approximately 10 years old with many low flexible hangers; the other about 40 years old and representative of older trees with no low hanger and small hangers on secondary wood. The trees were first shaken in one direction, then a second shake was applied in the same direction or at 30, 45, 60, or 90 degrees from the original direction. Limb shaking and circular translation at the trunk were also compared. The results indicate a definite advantage in applying the shaking force at more than one direction with those approaching 90 degrees being most effective. Circular translation was somewhat more effective than the one direction shake but much less effective than the two directions 90 degrees apart. The removal of fruit by limb shaking was equivalent to or greater than any of the trunk shaking procedures.

10. Bark damage. Thousands of trees are now being harvested with tree shakers. Any break in the bark is an opening for disease and insects and, therefore, bark damage must be prevented. A new pad was developed for the use on shakers for cherry trees. This corrugated surface, sponge rubber backed pad eliminated all bark damage for cherry trees. The new experimental C-clamp with five prongs on each face was tested and limbs could be shaken at up to 65 degree angle without slippage. The 10 small punctures in the limb did not seem to hurt the tree but it now looks like this type of a clamp will not be necessary.

A test of bark strength as related to soil and bark moisture conditions was conducted on prune-orchard plots of four different irrigation treatments. Bark strength, soil moisture, and bark moisture were taken at 7- to 10-day intervals for a period from July 22 to September 16. An analysis of the bark strength shows that, in all three plots irrigated after June 15, a reduction in bark strength occurred around the end of July; whereas the non-irrigated plot did not exhibit this reduction but remained approximately

constant. Therefore, the bark strength was affected by moisture conditions early in the season during the period of tree growth, but there was very little difference at the time that harvest commenced.

Tests of bark strength as related to tree age were conducted in two orchards; one with a tree age span of 4 to 23 years and the other from 6 to 17 years. In one orchard, bark strength was lowest for 6-year-old trees (225 p.s.i.), gradually increased to 13-year-old trees (265 p.s.i.), but was slightly lower again for 17-year-old trees (255 p.s.i.). A test in the second orchard showed bark strength gained fast from 4 to 9 years, but only slightly from 9 to 23 years.

A check of prune varietal differences on two different dates in one orchard showed Robe bark strength to be lowest, with French next (25 to 50 p.s.i. greater), and Imperial highest (10 p.s.i. over French). A test in another orchard again showed Robe lowest, but Imperial next (25 p.s.i. greater), and French highest (20 p.s.i. greater). An interesting observation from the results of this test was the large difference (100 p.s.i.) that was evident for the same age trees in two different areas in Sacramento Valley. A test was conducted in the University orchard to compare prune, apricot, peach, and almond species. Bark strength measurements showed Texas almond, Blenheim apricot, and Red Haven peach to have approximately the same strength (270 to 280 p.s.i. dry) and French prunes to be slightly lower (240 to 250 p.s.i.).

Tests of the attachment of shakers to "bolts" permanently installed in trees were continued. Lag screws, screw nails, and reddy bolts of 1/2- to 1-inch diameter were tested in both limbs and trunks. Screws and nails were installed in holes one-eighth-inch smaller in diameter than the fastener, and the bolts in holes one-eighth-inch greater in diameter. Lag screws seem to be most practical to install considering ease and speed of installation cost and minimum reduction of strength of limb. During field trials the smaller size fasteners were found to be subject to withdrawal, flexure, and breakage. Larger sizes were found to be satisfactory when the shaking force was approximately in line with the bolt ( $\pm$  20 to 30 degrees). With excessive side force, mild steel failed in bending and high strength steel resulted in crushing of wood adjacent to the bolt and near the bark. Both problems were minimized by minimum overhang of the fastener and results may be satisfactory.

A small compact shaker unit was developed and constructed to permit perpendicular attachment on limbs to eliminate the problem of longitudinal failure of bark which results when shaking at too great an angle. Preliminary tests were favorable and presently a powered arm for supporting and positioning the shaker unit is being developed.

11. Coffee harvesting. A coffee-harvesting labor supply outside the farm family is practically nonexistent in Kona, Hawaii. Since harvesting accounts for over 70 percent of the total farm labor input for coffee production, a grower's income is limited by the amount of coffee the farm family can harvest. This income is marginal and the Kona coffee industry will perish unless an economically feasible method of increasing harvest rate is devel-

oped. The Agricultural Engineering Research Division of the USDA and University of Hawaii are working on a cooperative project to accomplish this goal. Mechanical tree shakers have been designed and tested. The results demonstrate the feasibility of removing fruit by machine. A small scale model of a collapsible catching frame which can maneuver among closely spaced trees and rough, uneven terrain was constructed. The principle of pneumatic conveying was tested on coffee cherries and the results were entirely satisfactory. A small hand-held vibrator, manufactured commercially for cultivated blueberries, was obtained and tested. Results of short period tests show that the unit increases harvest rate, in a complete fruit removal operation, over that of a good hand picker. Results of measurements of coffee tree accelerations due to mechanical shaking illustrates what is happening to the tree. This information is useful in evaluating the present shaker and offers suggestions for improving it or designing a different one.

### C. Potato Harvesting Equipment

1. Mechanical injury of potatoes. Bruising continues to be one of the major problems in harvesting and handling potatoes. The impact instrument, which was developed on this project to measure susceptibility to bruising, was modified and the method of evaluating injury changed. In 1963, tubers were classified as injured or not injured. In 1964, four classifications of injury were recorded (none, slight, moderate, severe). Index numbers were applied to injuries (0, .1, .5, 1.0) and the sum for a 50-tuber sample was tentatively considered to be the injury index of the sample. In order to have a reproducible procedure for measuring the extent of an injury to a tuber, a device with a curved knife and gaging pin was constructed. This device proved to have considerable merit as a research tool. This knife may also be of value to the inspection people who grade potatoes. It now seems probable that a technique can be developed that will provide an injury index that will bear a reliable correlation with relative injury susceptibility.

Additional data were obtained on the cantilever flap rubber cushioning which was mentioned in last year's report. Results showed that it did not shorten chain life and does result in less bruising and better soil separation. Cantilever flap rubber cushioning is now available commercially.

2. Multi-row harvesting of potatoes. Potato harvesters have become more expensive and heavier each year. Anything which can be done to increase the acreage a unit can harvest and reduce soil compaction is desirable. Commercial direct-indirect (multi-row) harvesting methods (described in last year's report) were studied. Such advantages as machine cost savings of 20 to 30 percent were noted. Disadvantages such as lack of suitable devining equipment and need of modification of present equipment owned by growers were also observed.

3. Dust applicator for seed potatoes. Studies conducted by pathologists have shown that cut seed treatment prevents seed piece decay. The application of chemicals by dipping these seed pieces in a solution has serious

limitations. Although dusting has many advantages, no commercial equipment for uniform application insuring complete coverage of the seed piece surface is available. Several experimental units were constructed to (1) cover cut surfaces completely and uniformly, (2) contain dust to avoid dust contamination of this work area, and (3) have adequate capacity for commercial usage. The last unit met requirements (1) and (3) but does not contain the dust adequately. Modifications are being made and the unit will be tested in the spring and fall of 1965.

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ELECTROMAGNETIC AND ULTRASONIC ENERGY  
FOR INSECT CONTROL

Agricultural Engineering Research Division, ARS

Problem. Electromagnetic radiation has many established farm uses but research indicates many other highly useful potential capabilities in farm production, such as killing insects harmful to stored grain without leaving residues. Annual losses in recent years due to insects in field crops stored on the farm approximate 200 million dollars. To minimize the use of possibly hazardous chemicals and their residues in food products as much as possible, there is need for widespread investigation of non-chemical pest control methods, such as study of insect response to all possible types of radiation and sound and exploitation of weak physical links in the life of particular insects. There is need for development of better electric insect survey traps to sample insects in flight, and to permit control programs to be timed with greater accuracy. Since there is zero tolerance of DDT in milk, there is need for an electrical or physical means of controlling flies in and around dairy barns and milk houses. There is need for detecting or removing insects in food processing plants, including fruit flies in tomato canning plants, and larvae of the cabbage looper and imported cabbage worm that may be clinging to spinach leaves when delivered to the processing plant. The promising results of a project to control tobacco hornworm with only three traps per square mile using ultraviolet radiation as the attractant in a newly designed blacklight insect trap has raised the question, "What other insects can be controlled by electrical methods and equipment alone or in combination with insecticides, chemosterilants, and biological attractants?" Production of many crops is hampered by poor, slow, or non-uniform emergence of seedlings after the seed is planted. Some electrical treatments have been found to accelerate germination and seedling emergence. If emergence in the field can be speeded up and better uniformity obtained, weed control can be much more effective, with resulting increased efficiency in production of crops. Treatments also increase the percentage of germination for some seeds and would therefore enable the establishment of good stands with lower investments for seed. Further, uniform emergence tends toward more uniform maturation with increased practicability of once-over harvest programs.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research involving agricultural and electrical engineers and physicists working cooperatively with USDA entomologists and with the Experiment Stations of eleven States. Electrical and physical methods for corn borer control are studied in Iowa, and vegetable insect control and light trap design are being investigated in California and Indiana, with financial assistance from the Indiana Electric Association through the Purdue University Experiment Station. Research on electromagnetic energy for control of insects in stored grains and seeds is carried on in Nebraska and for conditioning seed to improve germination and emergence in Nebraska, Tennessee, and Washington.

design in California and Indiana, with financial assistance from the Indiana Electric Association through the Purdue University Experiment Station. Fly control in dairy barns is studied at Beltsville, Maryland. Research on electromagnetic energy for control of insects in stored grains and seeds is carried on in Nebraska and for conditioning seed to improve germination and emergence in Nebraska, Tennessee, and Washington.

Studies relating to potential use of radiofrequency (RF) energy for insect control and improvement of seed germination are in cooperation with the Departments of Agricultural Engineering, Entomology, and Agronomy at the Nebraska Agricultural Experiment Station. Cooperative help on some phases of studies was furnished by the Crops Research Division, ARS, the Asgrow Seed Company, the Agricultural Engineering Departments of the University of Idaho and Texas A&M University, and others.

Studies on effects of electric glow-discharge radiation on seeds and plant products have been continued at Knoxville, Tennessee in cooperation with the Departments of Agricultural Engineering, Agronomy, and Nutrition of the Tennessee Agricultural Experiment Station and the Crops Research Division, ARS. At Pullman, Washington, effects of glow-discharge radiation on germination of seeds and early plant growth were studied in cooperation with the Washington Agricultural Experiment Station, Washington State University.

The Federal scientific effort devoted to Agricultural Engineering research in this area totals 14.3 professional man-years; of this number 5.9 are devoted to electric traps for insect survey, destruction and control; components and design of electric insect traps for survey and control

#### PROGRAM OF STATE EXPERIMENT STATIONS

Several of the States are engaged in programs of basic and applied research on the possible use of some of the various forms of electrical and physical energies as a means for improvement of the potential capabilities in farm production.

Investigations in progress, many of which are cooperative with the Department, involved the evaluation of the use of radiofrequency energy for treatment of grains to destroy insect infestation and treatment of seeds to improve their germination characteristics; exploration of the feasibility of using ultrasonics and electric shock to control rats, mice and birds; studies of the possibilities for a major advancement in the technology of small particle depositions through the application of electrostatic, thermal or other inertial forces; and use of light sources of various wavelengths for attracting and collecting insects which infest many of our economic crops.

A total of 2.0 professional man-years effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Electric Traps for Survey, Destruction and Control of Vegetable Insects

Research on control of vegetable insects using electric light traps, on use of traps for insect survey, and on response of economically important insects to electromagnetic radiations was conducted in Indiana. This work was cooperative with the Purdue University Agricultural Experiment Station through the Departments of Agricultural Engineering and Entomology and was partially supported by the Indiana Electric Association.

Electric traps for determination of the migration and occurrence of corn earworm moths and occurrence of several other insect species of economic importance were studied in cooperation with personnel of the Purdue Department of Entomology as part of Regional Project NC-67, Migration of Aphids and Noctuids.

Field experiments to investigate the effectiveness of electric insect traps for controlling insect damage in tomato production were expanded and continued for the seventh consecutive season at Lafayette, Indiana. Studies were made in experimental garden areas using three types of insect traps. Fan, gravity, and electrocutor-grid traps were equipped with five 15-watt blacklight (BL) fluorescent lamps as attractants. Two traps were placed 750 feet apart in each of three 900-foot-long strips of tomato plantings with each strip 250 feet apart. Effectiveness of the traps in protecting tomatoes from tomato and tobacco hornworms, corn earworms (tomato fruitworms), cutworms, and drosophila was evaluated on the bases of insect infestation, plant foliage and fruit damage, and insect catch counts. Effectiveness of control was studied relative to distance from light traps. Traps were the only control measure used to protect the tomatoes from insect damage.

There was no appreciable difference in effectiveness of the three trap types tested. Fan traps collected and held a few more insects than did gravity traps, but the difference was not significant. Hornworms were more abundant than in 1963, with about 50 percent less parasitism. Hornworm-damaged ripe fruit increased gradually from 0.7 percent within 24 feet of the traps to 3.2 percent in an area 336 to 360 feet from the traps. Hornworm-infested tomato plants gradually increased from 49 percent within 24 feet of the traps to 67 percent at the greater distance. Foliage destroyed on plants near the traps was less than 0.1 percent of the total, and that on plants farthest from the traps was about 0.3 percent.

The population of corn earworm moths was much larger than in any year since 1959. Despite this large population, only 0.17 percent of 133,265 fruits harvested within 372 feet of the traps was infested. Fruit infestation in unprotected plantings in the surrounding county area varied from 0 to 9 percent.

Cutworm infestation was uniformly about 6 percent throughout the test area. Although many cutworm moths were caught in the traps, no appreciable control was effected. Microscopic examination of exposed tomato halves showed no drosophila infestation in the lighted field.

This season's work indicates that tomato plants and fruit may be protected satisfactorily from hornworms and corn earworms by blacklight insect traps without the use of insecticides, and that blacklight traps will not adequately protect the fruit from cutworms.

Field studies were continued to determine the time of night that corn earworm, tobacco hornworm, and tomato hornworm flights occur. Corn earworm moths were active from about one-half hour before sunset to sunrise and were captured in equal numbers from 8 p.m. until daybreak. Tobacco and tomato hornworm moths were captured during all hours of the night, with catches greatest in the morning hours.

A new project was initiated (March 1965) in cooperation with Entomology Research Division, ARS, and the California Agricultural Experiment Station, Riverside to study electric light traps for use on cabbage loopers. An experiment in Riverside, California has been designed to determine whether female sex attractants can be used to increase the catches of male cabbage loopers in insect light traps. An experiment has been started in Mesa, Arizona, in cooperation with the Entomology Research Division, to determine the effectiveness of (blacklight) traps in catching cabbage looper moths, and to determine the dispersal of the moths in the field. Future tests will be run to develop equipment for optimum performance in the arid Southwest, and for effective use against a variety of species. Ultimate application of the equipment is to reduce or eliminate the use of pesticides wherever practical.

#### B. Radiofrequency and Glow-discharge Equipment for Insect Control in Vegetable Seeds

Studies relating to potential use of radiofrequency (RF) energy for insect control and improvement of seed germination have been continued. Investigations were directed toward developing basic information and evaluating possible agricultural applications. The research is cooperative with the Departments of Agricultural Engineering and Entomology at the Nebraska Agricultural Experiment Station. Substantial cooperation has also been provided by Crops Research Division, ARS, USDA; the Asgrow Seed Company; the Agricultural Engineering Departments of the University of Idaho and Texas A&M University; and others.

In previous cooperative research with the Asgrow Research Center, Twin Falls, Idaho, RF treatments have accelerated germination of spinach seed and increased germination in seed lots of garden peas and beans containing hard seeds. Glow-discharge radiation reduced the hard-seed content of Kentucky Wonder beans. Acceleration of spinach seed germination was observed for the third consecutive year in tests this year which involved RF treatment of three different

seed lots. Other seed treated included cabbage, cantaloupe, cucumber, egg-plant, lettuce, onion, pepper, and tomato, but significant improvements were not obtained with these seeds this year.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Electric Traps for Insect Survey, Destruction and Control

Deay, H. O., Taylor, J. G. (deceased), and Barrett, J. R. 1964. Light trap collections of corn earworm adults in Indiana in the years 1953-1963. Proc. of North Central Branch, Entomological Society of America. 19:45-52. (Abstract)